



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>



GODFREY LOWELL CABOT SCIENCE LIBRARY
of the Harvard College Library

This book is
FRAGILE
and circulates only with permission.
Please handle with care
and consult a staff member
before photocopying.

Thanks for your help in preserving
Harvard's library collections.

34-157

Eng



GODF





1. See Opposite.

2. Johnson & Higgins. A Brief Résumé
of the Undersigned's Experience and
Connections with Dr. Chas. F. Barnes' In-
covery to prevent the Amerlustation of
Boilers. [New York? 1864?

Chandler, C. F.
U

REPORT
ON
WATER FOR LOCOMOTIVES
AND
BOILER INCRUSTATIONS:
MADE TO THE
PRESIDENT AND DIRECTORS
OF THE
New York Central Railroad.

BY
CHARLES F. CHANDLER, PH.D.,
PROFESSOR OF ANALYTICAL AND APPLIED CHEMISTRY IN THE SCHOOL OF MINES,
COLUMBIA COLLEGE, NEW YORK.

NEW YORK:
PRINTED BY JOHN F. TROW & CO. 50 GREENE STREET.
1865.

REPORT
ON
WATER FOR LOCOMOTIVES
AND
BOILER INCRUSTATIONS:

MADE TO THE
PRESIDENT AND DIRECTORS
OF THE
New York Central Railroad.

BY
CHARLES F. CHANDLER, PH.D.,
PROFESSOR OF ANALYTICAL AND APPLIED CHEMISTRY IN THE SCHOOL OF MINES,
COLUMBIA COLLEGE, NEW YORK.

NEW YORK:
PRINTED BY JOHN F. TROW & CO. 50 GREENE STREET.
1865.

Eng 2668.65

1866

1866

P. 1866

1866

REPORT.

THE following investigations were undertaken with the object of diminishing, as far as possible, the bad effects of the impure water supplied to locomotives on the section of the New York Central Railroad between Syracuse and Rochester. The large quantities of sulphate of lime and of the carbonates of lime and magnesia which these waters contain give rise to incrustations, varying from a loose mud to a hard crystalline scale. These deposits form a non-conducting lining to the boiler, involving loss of heat and consequent waste of fuel, and at the same time cause an over-heating of the metal, sometimes resulting in destructive explosions.* The quantity of incrustation produced varies greatly. As much as thirteen hundred pounds has been taken from a boiler at one time, though this is an extreme case. The most serious injury from these waters is suffered, however, by the lower plates of the boilers, which are rapidly corroded in deep furrows and pits and are sometimes even completely perforated, particularly along joints and about braces.

In planning these investigations it was considered desirable :

- I. To subject the waters to careful analysis.
- II. To analyze the incrustations.

* For two cases of explosions referred to deposits, see *Report of the Commissioner of Patents to the Senate of the United States, on the subject of Steam Boiler Explosions*. Read Jan. 8, 1849.

III. To examine the various articles and methods in use for preventing incrustations and corrosion.

IV. To institute a series of experiments on the boilers themselves.

I.—ANALYSIS OF THE WATERS.

Great care was taken to select the samples of water at such times as would insure a fair average quality; none being taken during the dry season, when the waters are low, nor soon after rains or thaws. The results of the analyses are reduced to the number of grains of impurity contained in one United States gallon of 231 cubic inches or 58318 grains. For the method employed in the analysis, and the plan of distributing the acids and bases, see the Appendix.

SYRACUSE.

No. 1. Onondaga Creek, from near the Fayette Street Bridge.

No. 2. Hydrant, near the New York Central Railroad Machine shop.

No. 3. The New Reservoir, soon after the water was let in.

	1 Onondaga Creek.	2 Hydrant.	3 New Reservoir
Chloride of Potassium.....	0.32 grs.	0.24 grs.	0.32 grs.
Chloride of Sodium.....	2.14 "	....	6.67 "
Sulphate of Potassa.....	....	0.07 "	....
Sulphate of Soda.....	0.98 "	0.07 "	1.92 "
Sulphate of Lime.....	10.68 "	16.71 "	12.36 "
Carbonate of Lime.....	7.25 "	6.84 "	5.77 "
Carbonate of Magnesia....	4.31 "	3.69 "	3.91 "
Oxide of Iron and Alumina..	0.06 "	0.06 "	0.08 "
Silica	0.28 "	0.25 "	0.14 "
Organic Matter.....	0.34 "	trace "	1.73 "
Total per gallon.....	26.36 grs.	27.93 grs.	32.90 grs.

No. 3 cannot be considered as fairly representing the New Reservoir ; the water, having just been let in, contained an unusual proportion of chloride of sodium and organic matter, the proportions of which would diminish in a few months ; when the water would not probably differ materially from the hydrant water, No. 2.

WARNER'S.

The sample was taken from the cask which receives the drip from the tank.

Chloride of Potassium	1.91	grs.
Sulphate of Potassa.....	1.81	"
Carbonate of Potassa.....	2.17	"
Carbonate of Soda.....	6.09	"
Carbonate of Lime.....	7.17	"
Carbonate of Magnesia.....	3.63	"
Oxide of Iron and Alumina.....	0.11	"
Silica.....	0.37	"
Organic Matter.....	0.37	"

Total per gallon.....23.63 grs.

This water is very remarkable in containing a considerable quantity of the carbonates of potassa and soda ; neither of which was found in any of the other waters analyzed. As these salts are among the most effective agents for decomposing sulphate of lime and preventing the formation of the hard crystalline incrustations, this water might be considered a natural remedy, and the locomotives might be sent "to the springs" for the same reason that certain invalids are sent to Saratoga. The good qualities of this water are, however, more or less overbalanced by the large proportion of the chlorides of potassium and sulphate of potassa present, which is nearly double the average quantity found in the waters.

MEMPHIS.

The sample was taken from the brook which supplies the tank.

Chloride of Potassium.....	0.29	grs.
Chloride of Sodium.....	0.26	"
Sulphate of Soda..	0.86	"
Sulphate of Lime...	10.12	"
Carbonate of Lime....	6.75	"
Carbonate of Magnesia.	4.41	"
Silica.....	0.31	"
Oxide of Iron and Alumina.....	0.09	"
Organic Matter.....	0.18	"
<hr/>		
Total per gallon.....	22.77	grs.

JORDAN.

No. 1. From the cistern, supplied from the Skaneateles outlet, through the mill race. This water was supposed to differ materially from that of the outlet, on account of a spring which flowed into it near the mill race.

No. 2. Skaneateles outlet, taken from under the railroad bridge.

No. 3. A brook formerly used.

	1 Mill Race.	2 Skaneateles Outlet.	3 Brook.
Chloride of Potassium.....	0.33 grs.	0.65 grs.	0.56 gra.
Chloride of Sodium.....	0.76 "	7.52 "	
Chloride of Magnesium.....	..	0.69 "	
Sulphate of Soda.....	0.62 "	..	32.54 grs.
Sulphate of Lime.....	4.02 "	10.60 "	
Carbonate of Lime.....	5.03 "	1.41 "	
Carbonate of Magnesia.....	2.30 "	2.01 "	
Oxide of Iron and Alumina.....	0.03 "	0.03 "	
Silica.....	0.09 "	0.18 "	
Organic Matter.....	0.06 "	0.76 "	
<hr/>			
Total per gallon	13.24 grs.	23.85 grs.	33.10 grs.

It will be seen from the figures that the water from the mill race differs very materially from that of the outlet, the better water being that which is now supplied to locomotives. The difference is more apparent when the results of the analysis are thus presented :

	1 Mill Race.	2 Skaneateles Outlet.
* Corroding Constituents.....	1.71 grs.	8.86 grs.
† Sulphate of Lime.....	4.02 "	10.60 "
Other incrusting Constituents...	7.45 "	3.63 "

It is very fortunate that this important station is supplied with water of such comparatively fair quality.

WEEDSPORT.

Weedsport is not a water station, although the propriety of erecting a tank here has been discussed. In the field, directly in the rear of the station, are three springs, nearly on a north and south line, but a few rods from each other. The north spring supplies a pump at the station, while the water of the middle spring flows into the south spring, and the two combined supply the adjacent mill, the water escaping finally by a spout.

The waters are clear, sparkling, and agreeable, and are, therefore, considered very pure. The presence of lime was suspected from the abundance about the springs of little "snails" (*Physa heterostropha*) with their calcareous shells ; and it was confirmed by an examination of the twigs and pebbles upon which the water from the mill spout falls. These were covered with a calcareous incrustation (tufa) in some cases half an inch thick. The results of the analysis were as follows :

No. 1. North Spring. Sample taken from the pump at the station.

* Corroding refers here to the boiler plates.

† Sulphate of Lime renders hard and crystalline the deposits which would otherwise be muddy and loose.

No. 2. Middle Spring.

No. 3. South Spring.

No. 4. Middle and South Spring. Sample taken from the mill spout.

	1 North Spring Pump.	2 Middle Spring.	3 South Spring.	4 Mill Spout.
Chloride of Potassium.....	0.26 grs.	0.36 grs.	0.52 grs.	0.48 grs.
Chloride of Sodium.....	0.02 "			
Sulphate of Soda.....	0.69 grs.	25.19 "	25.96 "	25.72 "
Sulphate of Lime.....	7.94 "			
Carbonate of Lime.....	6.30 "			
Carbonate of Magnesia.....	4.79 "			
Oxide of Iron and Alumina.....	0.07 "			
Silica.....	0.36 "			
Organic Matter.....	0.75 "			
Total per gallon.....	21.18 grs.	25.55 grs.	26.48 grs.	26.20 grs.

As Port Byron, with the purest water between Syracuse and Rochester, is only $3\frac{1}{4}$ miles distant, it would not be at all advisable to erect a tank at this point, to supply such impure waters.

PORT BYRON.

This is a very important water station. The water is drawn from Owasco Creek, the outlet of the Owasco Lake. The sample was taken from the tank.

Chloride of Potassium.....	0.39 grs.
Sulphate of Potassa.....	0.32 "
Sulphate of Soda.....	0.37 "
Sulphate of Lime.....	0.01 "
Carbonate of Lime.....	5.43 "
Carbonate of Magnesia.....	1.57 "
Silica.....	0.16 "
Oxide of Iron and Alumina.....	trace
Organic Matter.....	1.28 "
Total per gallon.....	9.53 grs.

This is the purest water analyzed. It contains hardly a trace of sulphate of lime.

Mr. S. Smith informed me that no scale is formed from this water in the boiler connected with the pumping engine ; the deposit instead of being hard and crystalline (characters due to sulphate of lime) is a soft mud, readily removed from the boiler.

SAVANNAH.

No. 1. From the tank ; drawn from a spring, one mile distant.

No. 2. From Black Creek, one mile west of the station.
Not used.

	1 Tank.	2 Black Creek.
Chloride of Potassium.....	0.59 grs.	0.48 grs.
Chloride of Sodium.....	..	4.80 "
Sulphate of Potassa.....	0.07 "	..
Sulphate of Soda.....	0.69 "	..
Sulphate of Lime.....	..	7.17 "
Carbonate of Lime.....	11.93 "	8.98 "
Carbonate of Magnesia.....	5.04 "	4.20 "
Oxide of Iron and Alumina.	0.10 "	trace "
Silica.....	0.56 "	0.58 "
Organic Matter.....	1.52 "	2.76 "
Total per gallon.....	20.50 grs.	28.97 grs.

It will be seen by the analyses, that the water of the tank is much purer than that of Black Creek, containing neither sulphate of lime nor chloride of sodium.

	1 Tank.	2 Black Creek.
Corroding Constituents.....	1.35 grs.	5.28 grs.
Sulphate of Lime.....	..	7.17 "
Other incrusting Constituents..	17.63 "	18.76 "

CLYDE.

A very important station :

No. 1. From the tank. Spring water.

No. 2. From the river.

	1 Spring.	2 River.
Chloride of Potassium.....	0.14 grs.	0.52 grs.
Chloride of Sodium.....	..	0.37 "
Sulphate of Potassa.....	0.18 "	..
Sulphate of Soda.....	0.45 "	1.21 "
Sulphate of Lime.....	..	4.40 "
Carbonate of Lime.....	9.66 "	6.07 "
Carbonate of Magnesia.....	4.41 "	3.03 "
Oxide of Iron and Alumina.....	trace	trace
Silica.....	0.58 "	0.80 "
Organic Matter.....	2.16 "	1.88 "
Total per gallon.....	17.58 grs.	18.28 grs.

Although these two waters contain nearly the same number of foreign constituents, they differ materially in character ; as will be more clearly seen in the following statement

	1 Spring.	2 River.
Corroding Constituents.....	0.77 grs.	2.10 grs.
Sulphate of Lime.....	..	4.40 "
Other incrusting Constituents.....	14.64 "	9.90 "

LYONS, NEWARK, AND PALMYRA.

No. 1. Lyons. Mill Race, Canandaigua Outlet. Sample taken from the cistern near the tank.

No. 2. Newark. Sample taken from the tank.

No. 3. Palmyra. Sample taken from the tank. Water drawn from Red Creek.

	1 Lyons.	2 Newark.	3 Palmyra Red Creek.
Chloride of Potassium.....	0.29 grs.	0.47 grs.	0.76 grs.
Chloride of Sodium.....	..	0.38 "	..
Sulphate of Potassa.....	0.03 "	..	..
Sulphate of Soda.....	0.71 "	0.32 "	0.67 "
Sulphate of Lime.....	3.17 "	3.19 "	18.81 "
Carbonate of Lime.....	4.38 "	9.15 "	8.41 "
Carbonate of Magnesia.....	3.34 "	6.01 "	5.98 "
Oxide of Iron and Alumina.....	trace	0.08 "	0.02 "
Silica.....	0.18 "	0.30 "	0.17 "
Organic Matter.....	1.00 "	2.16 "	1.46 "
Total per gallon...	18.10 grs.	22.07 grs.	36.28 grs.

The Palmyra water is one of the most impure analyzed. In total impurity it is only surpassed by the water of the North Street well in Rochester, and it contains the largest quantity of sulphate of lime found. It is quite possible that the water of Mud Creek, which joins the Red Creek near the station, may be better; my attention having been called to the proximity of Mud Creek quite recently it is not possible to present an analysis.

MACEDON AND FAIRPORT.

No. 1. Tank in the swamp between Macedon and Fairport.

No. 2. Thomas Creek at Fairport—the most important station on the road.

	1. Macedon Swamp.	2. Thomas Creek.
Chloride of Potassium.....	0.14 grs.	0.34 grs.
Chloride of Sodium.....	..	0.69 "
Chloride of Magnesium.....	..	2.16 "
Sulphate of Potassa.....	0.18 "	..
Sulphate of Soda.....	0.89 "	..
Sulphate of Lime.....	0.14 "	8.72 "
Carbonate of Lime.....	7.68 "	5.07 "
Carbonate of Magnesia.....	2.23 "	1.03 "
Oxide of Iron and Alumina	trace	0.04 "
Silica.....	0.48 "	0.20 "
Organic Matter.....	0.80 "	1.14 "
Total per gallon.....	12.04 grs.	19.39 grs.

The swamp water is remarkable for the small quantity of alkaline salts and sulphate of lime: the Creek water for the presence of so large a quantity of chloride of magnesium.

ROCHESTER.

No. 1. North Street well. Spring water.

No. 2. Genesee River. Sample taken from the tank at the pump-house.

No. 3. Canal water. Sample taken from the tank at the round-house.

	1 North St. Well.	2 River.	3 Canal.
Chloride of Potassium.....	0.96 grs.	0.28 grs.	0.33 grs.
Chloride of Sodium.....	4.82 "	0.05 "	0.17 "
Chloride of Magnesium	1.53 "	....	....
Sulphate of Soda.....	....	0.85 "	0.61 "
Sulphate of Lime.....	6.46 "	3.16 "	2.16 "
Carbonate of Lime.....	16.92 "	4.64 "	4.30 "
Carbonate of Magnesia.....	8.88 "	2.06 "	1.81 "
Oxide of Iron and Alumina.....	0.10 "	0.09 "	0.05 "
Silica	0.90 "	0.90 "	0.18 "
Organic matter.....	1.60 "	1.64 "	1.24 "
Total per gallon.....	42.17 grs.	13.67 grs.	11.15 grs.

The water of the North Street well is the most impure analyzed, containing 7.31 grs. of corroding saline matter, including chloride of magnesium, found in only two other waters, and 33.26 grs. of earthy salts which form incrustations.

The waters of the Genesee River and Canal are almost identical, which might have been expected.

The analyses of the waters actually supplied to locomotives are tabulated on the next page for comparison.

COMPOSITION OF WATERS NOW SUPPLIED TO LOCOMOTIVES.

STATIONS.	CORRODING CONSTITUENTS.					INCORUSTING CONSTITUENTS.							INCORUSTATION PARALLELS.		TOTAL	
	Chloride of Potassium.	Chloride of Sodium.	Chloride of Magnesium.	Sulphate of Potassa.	Sulphate of Soda.	Sum.	Sulphate of Lime.	Carbonate of Lime.	Carbonate of Magnesia.	Oxide of Iron.	Silica.	Sum.	Carbonate of Potassa.	Carbonate of Soda.		Organic Matter.
Syracuse, Onondaga Creek.....	0.32	2.14	.....	.....	0.98	3.44	10.68	7.25	4.31	0.06	0.28	22.53	.....	.....	0.34	26.36
" " Hydrant.....	0.24	.....	0.07	.....	0.97	0.38	16.71	6.84	3.69	0.06	0.25	27.55	.....	.....	trace	27.93
Warner's.....	1.91	.....	1.81	.....	0.97	3.72	7.17	3.63	0.11	0.37	0.18	21.58	2.17	6.09	0.37	23.63
Memphis.....	0.29	0.26	.....	.....	0.36	0.91	10.12	6.75	4.41	0.09	0.31	21.68	.....	.....	0.18	22.77
Portland.....	0.33	0.76	.....	.....	0.62	1.71	4.02	5.93	2.30	0.03	0.09	11.47	.....	.....	0.06	13.24
Port Byron.....	0.39	.....	.....	.....	0.37	1.08	0.01	5.43	1.57	trace	0.16	7.17	.....	.....	1.28	9.63
Savannah.....	0.59	.....	0.32	.....	0.67	1.35	.....	11.93	5.04	0.10	0.66	17.63	.....	.....	1.52	20.50
Clyde: Spring.....	0.14	.....	0.07	.....	0.69	0.45	.....	9.66	4.40	trace	0.68	14.64	.....	.....	2.16	17.58
" River.....	0.52	0.37	.....	.....	1.21	2.10	4.40	6.07	3.03	trace	0.80	14.30	.....	.....	1.58	18.20
Lyons.....	0.29	.....	0.03	.....	0.32	1.03	3.17	4.38	3.34	trace	0.18	11.07	.....	.....	1.00	13.10
Newark.....	0.47	0.38	.....	.....	0.32	1.17	3.19	9.15	6.01	0.08	0.30	18.73	.....	.....	2.16	26.07
Palmyra.....	0.76	.....	.....	.....	0.97	1.43	18.51	8.41	5.98	0.02	0.17	33.39	.....	.....	1.46	36.28
Macedon Swamp.....	0.14	.....	0.18	.....	0.39	0.71	0.14	7.68	2.23	trace	0.48	10.63	.....	.....	0.80	12.01
Fairport.....	0.34	0.59	.....	.....	0.39	3.19	8.72	5.07	1.03	0.04	0.20	15.06	.....	.....	1.14	19.39
North Street well.....	0.96	4.52	1.53	.....	.....	7.31	6.46	16.92	8.88	0.10	0.90	33.26	.....	.....	1.60	42.17
Genesee River.....	0.28	0.05	.....	.....	0.85	1.18	3.16	4.64	2.06	0.09	0.90	10.85	.....	.....	1.64	13.67
" " Canal, Round House.....	0.33	0.17	.....	.....	0.61	1.11	2.16	4.60	1.81	0.05	0.18	8.80	.....	.....	1.24	11.15
Average.....	0.49	0.97	0.22	0.16	0.49	1.93	5.39	7.47	3.75	0.05	0.39	17.05	0.13	0.36	1.10	20.57

The numbers represent grains per gallon of 231 cubic inches.

It appears from the foregoing table, that the average composition of the water is :

Corroding constituents.....	1.93	grs.
Sulphate of Lime.....	5.39	grs. }
Carbonate of Lime.....	11.66	“ }
Carbonate of Magnesia.....		
Oxide of Iron and Silica }		
Organic matter.....	1.10	“
Incrustation preventives.....	0.49	“
		<hr/>
Total per gallon.....	20.57	“

As the incrustation preventives, carbonate of potassa and soda, occur in but one water, they need hardly be considered in this connection. The average does not represent the average composition of all the water used between Syracuse and Rochester, as more is used from some stations than from others ; nor, for the same reason, does it represent the average composition of the water which enters any one boiler. It is, however, the nearest possible approximation to these averages, and serves as a basis of comparison.

Twelve of the seventeen waters contain less than the average quantity of corroding constituents.

Eight contain less than the average quantity of sulphate of lime.

Ten contain less than the average of incrusting constituents.

Nine less than the average of total impurities.

The effect of the various constituents on the metal of the boilers and in forming incrustations, will be discussed in the latter part of the report.

In determining the comparative value of these waters, it is not safe to depend entirely on the relative quantities of total impurity ; nor is it possible to fix the comparative importance of the corroding constituents, the sulphate of lime, and the total quantity of incrusting constituents. A careful consideration, however, of all the data, leads me to value the waters as follows, beginning with the best :

BETTER THAN THE AVERAGE.

	Total Impurities.
1. Port Byron	9.58
2. Macedon Swamp	12.04
3. Rochester: Canal at Round House....	11.15
4. Clyde: Spring	17.58
5. Lyons	18.10
6. Rochester: Genesee River	18.67
7. Jordan	18.24
8. Savannah	20.50

POORER THAN THE AVERAGE.

9. Clyde: River	18.28
10. Warner's	23.63
11. Newark	22.07
12. Memphis	22.77
13. Fairport	19.39
14. Syracuse: Hydrant	27.93
15. " Onondaga Creek	26.36
16. Palmyra	36.28
17. Rochester: Well at North Street....	42.17

For the convenience of engineers, the following arrangement of the stations in their geographical order, numbered according to their quality, is made. Those below the average are indicated by a star, and should be avoided as much as possible.

- *15. Syracuse : Onondaga Creek.
- *14. " Hydrant.
- *10. Warner's.
- *12. Memphis.
- 7. Jordan.
- 1. Port Byron.
- 8. Savannah.
- 4. Clyde : Spring.
- *9. " River.
- 5. Lyons.
- *11. Newark.
- *16. Palmyra.

- 2. Macedon Swamp.
- *13. Fairport.
- *17. Rochester : North Street well.
- 6. " Genesee River.
- 3. " Canal, Round House.

II. ANALYSIS OF THE INCRUSTATIONS.

It was considered desirable to analyze a sufficient number of incrustations to determine with certainty their prevailing character. Although the analyses of the waters gave a tolerably good idea of the composition of the deposits, and made it certain that the chief constituents must be carbonate of lime, carbonate of magnesia, and sulphate of lime, a knowledge of the average proportions of these different constituents was essential to the proper selection of remedies ; as the carbonates and sulphates require different reagents for their solution. Ten incrustations were therefore selected ; six of them as fair average representatives of the usual deposits, and four as exceptional varieties.

The results of the analyses are tabulated on the next page. The method employed in the analysis, is given in the Appendix.

ANALYSES OF BOILER INCrustATIONS. §

SOURCE.	Structure.	Thickness.	Sulphate of Lime.	Carbonate of Lime.	Basis Carbonate of Magnesia.	Oxide of Iron and Alumina.	Water.	Organic Matter.	Silica.	TOTAL.	—
1. Stationary engine, boiler shop. Syracuse: Hydrant water.....	Compact and crystalline.	3-16ths in.	74.07	14.78	9.19	0.08	1.14	undet.	0.65	99.91	the usual representations of
2 *Stationary engine, machine shop. Rochester: Canal water, 10 mos. Well water, 2 mos.....	"	2 inches	71.37	.....	.....	28.871	.....	.....	1.76	100.00	
3. Locomotive, No. 211. Freight, both roads. Syracuse.....	"	1-32 inch.	62.86	12.62	18.95	0.92	1.28	undet.	2.60	99.23	
4. Locomotive: surrounding a brace..	"	1-4th to 1-32 inch.	53.05	.....	.....	42.161	.....	.....	4.79	100.00	
5. Locomotive, No. 127. Freight, both roads. Syracuse.....	"	1-32d inch.	46.83	.....	.....	47.851	.....	.....	5.32	100.00	
6. Locomotive, No. 202. Freight, both roads. Syracuse.....	"	1-4th inch.	30.80	26.93	31.17	1.08	2.44	undet.	7.75	100.17	
Average.....	....	....	56.49	18.11	19.77	0.69	1.62	undet.	3.81	....	....
7. †Stationary engine, Niagara Falls: River water.....	Friable and granular.	2 inches.	4.95	86.25	2.61	1.03	0.63	undet.	2.07	97.54	Exceptional in only ones, the crystallization, of their kind.
8. †Stationary engine, Townsend's Furnace, Albany.....	"	1½ inches.	0.88	93.19	2.84†	0.36	0.15	1.96	0.62	100.00	
9. Locomotive, No. 122. Rochester to Buffalo.....	Powder.	....	4.81	.....	.....	92.271	.....	.....	2.92	100.00	
10. Stationary engine. Earllyat and Greenhagh, Schenectady.....	"	....	30.07	.....	.....	61.691	.....	.....	8.24	100.00	

* A mass weighing 21 ounces, which had apparently filled the space between three tubes.

† A mass weighing 14 ounces, evidently detached from a tube.

§ For method of Analysis, see Appendix.
|| This number includes those belonging to the two preceding and the two following columns; as obtained by difference.

The incrustations appear to be of three kinds :

1. Hard, compact, and crystalline, formed of numerous thin layers, and consisting of from 30 to 75 per cent. of sulphate of lime, associated with carbonate of lime, basic carbonate of magnesia (2MgO , CO_2) etc. (Analyses 1 to 6.)

The average composition of the six specimens analyzed was,

Sulphate of Lime.....	56.49
Carbonate of Lime.....	18.11
Basic Carbonate of Magnesia.....	19.77
Oxide of Iron and Alumina.....	0.69
Silica.....	3.81
Organic matter.....	undet.
Water.....	1.62
	<hr/>
	100.00

With a single exception all the locomotive incrustations were of this character, as were also most of those from stationary boilers. The incrustations from marine boilers belong to this class, consisting almost entirely of sulphate of lime.

2. Loose and friable, not at all crystalline ; in thick masses, not in well-defined layers, composed chiefly of carbonate of lime. (Analyses 7 and 8.) Only two specimens of this variety were met with, both from stationary boilers. They are evidently deposited from water containing very little sulphate of lime.
3. Consisting of a fine powder or mud. Noticed in only two instances ; in one case in a locomotive, in the other in a stationary boiler. In composition the two specimens differ ; one consisting chiefly of carbonate of lime and magnesia, the other containing 30 per cent. of sulphate of lime. (Analyses 9 and 10.)

GENERAL CONCLUSIONS FROM THE ANALYSES.

THE FORMATION OF INCRUSTATIONS.

The analyses presented on page 17 show that the incrustations consist chiefly of the carbonates of lime and magnesia and the sulphate of lime. The two carbonates are insoluble in pure water, and owe their presence in the waters of springs and rivers to free carbonic acid, which forms with them soluble bicarbonates.

When such waters are boiled this carbonic acid is expelled, and the carbonates of lime and magnesia separate in the form of insoluble powders, portions of which adhere to the sides of the vessel containing the water.

The carbonic acid acting as a solvent is so loosely combined with the carbonates, that exposure to the air is sufficient to cause the separation of a portion of it, an equivalent quantity of the insoluble carbonates separating as a deposit, as already mentioned in connection with the Weedsport waters (page 7).

The more slowly the carbonates are precipitated from their solution in carbonic acid, the more compact are the deposits, and the more firmly do they adhere to the surfaces with which they come in contact. In caverns, by slow evaporation, hard stony stalactites and stalagmites are formed, while in boilers, unless sulphate of lime be present in considerable quantity, the deposits consist usually of a fine loose powder or mud.

Various alkaline substances, by appropriating this carbonic acid, cause the precipitation of the insoluble carbonates. Potash, soda, and ammonia, as well as their carbonates, produce this effect, as does also lime water. In the latter case, the lime added, unless an excess be used, is also deposited as carbonate; consequently no alkaline salts are substituted for the carbonate removed, as is the case when the other substances are employed.

It is seen from the above that the carbonates may be removed, without decomposition, by simply depriving them of their solvent, the carbonic acid.

The sulphate of lime is soluble in water, one part of the sulphate requiring about 400 parts of water for its solution. One gallon of water is capable of holding about 150 grains of sulphate of lime. The solubility of sulphate of lime in water is modified by the presence of other substances. The chlorides of calcium and magnesium, alcohol, etc., and even a high temperature diminish, while the chlorides of sodium and ammonium, sugar, and various other organic substances, somewhat increase its solubility. Hyposulphite of soda is said to increase its solubility tenfold. Above 212° F. the solubility rapidly diminishes as the temperature increases. At 255° F., equivalent to a pressure of 30 pounds, its solubility is diminished nearly three-fourths; at 272° F., equivalent to a pressure of 45 lbs., nineteen-twentieths, and at a temperature of 280° to 300°, it may be said to be totally insoluble.

The following analyses of waters taken from boilers are interesting in this connection :

	1.	2.	3.	4.
	No. 101.	No. 106.	No. 112.	Stationary, Machine Shop, Syracuse.
Distance run	700 miles.	416 miles.	416 miles.	
Road	direct.	Auburn.	Auburn.	
Preventive used . .	bran.	bran, 2 buck- ets.	nothing.	potatoes, one peck.
Reaction	neutral.	neutral.	neutral.	alkaline.
Sulphate of lime . .	17.88 grs.*	9.53 grs.*	39.89 grs.	49.82 grs.*
Carbonates of lime and magnesia . .	trace.	trace.	trace.	trace.
Chlorides, etc. . . .	56.76 "	19.38 "	52.95 "	37.42 "
Organic matter . . .	9.33 "	8.86 "	13.99 "	12.59 "
Nitrates	trace.		trace.	faint trace.
Total per gallon . .	83.97 grs.	37.77 grs.	106.83 grs.	99.83 grs.

* These figures are probably too high, as they are calculated from the sulphuric acid, a portion of which probably exists in the form of alkaline sulphates.

No. 106 had run for eight months, and was very clean. The water from the stationary was turbid, depositing on standing a sediment containing sulphate of lime, carbonates of lime and magnesia, oxide of iron, clay, etc. The small quantities of sulphate of lime and of the carbonates of lime and magnesia contained in these waters, confirm the statements already made with regard to the effect of heat on the solubility of these substances.

Sulphate of lime does not therefore require the presence of carbonic acid for its solution. It is deposited in boilers on account of the high temperature and its limited solubility, and forms, in the absence of the carbonates, as in marine boilers, a hard crystalline scale, sometimes an inch or more in thickness. When the carbonates of lime and magnesia are present the deposits vary from a loose powder to a hard crystalline incrustation, according to the relative proportions of the three substances.

In practice sulphate of lime can only be removed from water by undergoing decomposition ; for example, by carbonate of soda, which forms carbonate of lime, which is deposited as a powder, and sulphate of soda, which remains in solution. It has been stated (page 3), that as much as thirteen hundred pounds of incrustation has been taken from a single boiler at one time. It may seem impossible for so large a quantity of earthy matter to be deposited from waters which average only seventeen grains of incrusting constituents per gallon. When it is recollected, however, what vast quantities of water pass into a locomotive boiler, the possibility will be fully conceded. It was stated by a master mechanic on the Road, that a locomotive in running 40 miles will take in 1800 gallons of water, equivalent to 45 gallons per mile, a quantity which seems incredible.

Accepting this statement as a basis for calculation, we have 765 grains, or more than an ounce and a half of earthy matter as a possible average of the quantity which enters the boiler per mile. Multiplying this by 1988, the average

number of miles run on this section of the road by each of 56 locomotives, in one month (Dec.), we have 217 pounds of incrusting matter entering a boiler per month, or 2604 pounds per year. Nor is this necessarily a maximum, as some boilers receive the larger part of their water from stations furnishing water much below the average in purity.

THE EFFECT OF INCRUSTATIONS.

The injurious action of the incrustations is threefold :

1. Being very poor conductors of heat, and occupying a position between the boiler plates and the water, they cause a great loss of heat and consequent waste of fuel. This waste is estimated at 20 per cent., and in some cases as high as even 47 per cent. of the fuel used. Nor does this waste require a very thick incrustation, a very small fraction of an inch of scale being sufficient to exert a decided influence on the quantity of fuel necessary to produce the required power. This loss of heat involves, of course, a corresponding loss of power.

2. For the same reason they cause an over-heating of the boiler-plates, which often become red hot, though only separated from the water by a thin scale. Such over-heating is sure to cause a rapid burning out of the metal, and may result in an explosion of the boiler, should the expansion of the boiler-plates loosen and detach the scale so as to expose the over-heated surface to the water.

3. The corrosion of the metal occurs most rapidly in those parts of the boiler upon which the deposits are most liable to accumulate.

THE CORROSION OF THE BOILER PLATES.

The only substances contained in the water which can be supposed to act upon the iron, are the alkaline salts, chlorides of potassium and sodium, sulphates of potassa and

soda and chloride of magnesium. That these substances do affect iron is shown by introducing slips of iron and copper connected with a galvanometer into their solutions. A galvanic current is produced, which is a certain indication of chemical action ; although the short duration of such an experiment precludes the possibility of any considerable corrosion of the iron.

The impression which prevails among some of the employees of the Road, that the corrosion is due to some acid, is not confirmed by the analyses of the water. No free acid, except carbonic, exists in any one of them ; and the presence of the carbonates of lime and magnesia renders the existence of any other free acid impossible.

The copper and brass tubes, used in locomotive boilers on account of the rapidity with which they "make steam," must greatly facilitate the corrosion of the iron. The copper is rendered electro-negative, while the iron in the electro-positive condition is corroded. That the incrustations have some influence on the corrosion is proved by the fact that the plates which suffer most are those upon which the incrustations most rapidly accumulate ; the lower or "belly plates" of the boiler.

This coincidence may be owing to the fact that the deposits subside most readily in those parts of the boiler least disturbed by currents. It would be well to ascertain whether an arrangement by which the water entering the boiler could be made to produce currents in those parts not directly over the flues or fire box, would not materially diminish both the deposits and corrosion.

As a somewhat anomalous fact, it may be mentioned here, that even chemically pure (distilled) water is not adapted for "feeding" boilers. Some of the condensers used in connection with marine boilers, for condensing the waste steam, are found to furnish water which produces effects quite similar to those noticed in the locomotive boilers. It is even stated that the addition to this water of a small quantity of water con-

taining chloride of sodium and sulphate of lime (sea water) suffices to prevent the corrosion.

The corrosion of the locomotive boilers is not evenly distributed over the surface of the plates, but is confined to pits and grooves which are most abundant along joints, and in fact wherever the surface of the metal may have been bruised. The surface of the boiler plates is harder, and less readily attacked, than the interior; which it protects, as the skin of an apple protects its interior from decay. In trimming down the rough edges, where the plates lap and where braces are riveted to the plates, the boiler makers are liable to cut through this hard surface with their chisels, and at these points the corrosion is most rapid.

After a careful consideration of all the facts of the case, I am satisfied that the corrosion of the plates is due to the saline substances already mentioned, aided by the electro-positive condition of the iron (induced by contact with the copper or brass tubes); by the presence of bulky incrustations; and by the high temperature of the water.

III.—MEANS FOR PREVENTING INCRUSTATIONS AND CORROSION.

Numberless substances and methods have been proposed from time to time, for preventing the bad effects of impure water in boilers. Although it is beyond the plan of this Report to discuss, or even to mention them all, it is important that some general idea of the principles upon which their supposed efficacy is based, be given here.

Most of the methods are designed merely to prevent and remove incrustations; the opinion has been already advanced in these pages, however, that corrosion is much aggravated by the presence in the boiler of calcareous deposits. Methods which prevent incrustations, must therefore diminish corrosion. Some of the methods to be mentioned, are applied to

the water before it enters the boiler; in other cases, substances are introduced into the boiler itself. In most cases, the salts of lime and magnesia are either precipitated in fine particles as a loose mud, or rendered permanently soluble.

Filtration, which removes suspended impurities, is in this case useless, as the salts to be removed are in solution.

Distillation is particularly recommended, and employed to a considerable extent, for marine boilers using sea water. The anomalous behavior of distilled water has been already mentioned on page 22. This method of purification is entirely impracticable for locomotives.

Boiling expels the free carbonic acid, and causes the separation of the carbonates of lime and magnesia, and if conducted at a high temperature, under considerable pressure, results in the almost complete precipitation of the sulphate of lime. This would, however, merely transfer the incrustations from the locomotive boiler to some other vessel, and would therefore be valueless in this case.

Lime Water is employed on a large scale at Woolwich. The lime combines with the free carbonic acid, causing the precipitation of the carbonates of lime and magnesia. The proportion of lime water added varies with the amount of free carbonic acid present. In a few hours the carbonates settle, leaving the supernatant water clear. As the lime added is also deposited as carbonate, nothing is introduced which remains in solution. The sulphate of lime is not affected. This method is readily applied and inexpensive. It merely requires extra tanks for the lime water, and for settling the sediments. It is specially applicable to water containing little sulphate of lime.

Baryta Water, which affects the sulphate, as well as the carbonates, has been proposed, but its high price puts it entirely out of the question.

Carbonate of Soda.—This salt precipitates the carbonates of lime and magnesia, by withdrawing the free carbonic acid. It also decomposes the sulphate of lime, forming carbonate

of lime, which is deposited, and sulphate of soda, which remains in solution. This is very effective, and not expensive. Added in excess, however, it is said to produce priming and leakage. *Carbonate of potash* would answer the same purpose, but is more expensive : *caustic soda* and *potash* behave in nearly the same manner. *Carbonate of ammonia* has the same effect on the lime salts, but does not precipitate the magnesia. Carbonate of soda is preferable to the other substances of this class, on account of its low price.

It may be advisable to employ caustic soda in some cases, on account of its superior efficacy in loosening hard scales.

Chloride of Barium decomposes sulphate of lime, forming sulphate of baryta, which is deposited. This would be too expensive in this country, besides being objectionable on account of the chloride of calcium left in the water. *Hydrochloric acid* is sometimes added with the chloride of barium to dissolve the carbonates of lime and magnesia, and form the soluble chlorides of calcium and magnesium. In excess this acid would attack the boiler plates.

Carbonate of Baryta decomposes sulphate of lime, with the formation of sulphate of baryta and carbonate of lime, both of which separate as a deposit. The carbonates of lime and magnesia contained in the water are not affected. This method may be applied to water which has been freed from its carbonates by lime water, the carbonate of baryta being introduced into the boiler. *Carbonate of lead*, which behaves in a similar manner, has been suggested for the same purpose ; larger quantities would, however, be required, and it is much more expensive.

Chloride of Ammonium.—This salt is very effective in decomposing the lime and magnesia salts, even after they have been deposited, forming soluble chlorides of calcium and magnesium, carbonate of ammonia, which is rapidly expelled with the steam, and sulphate of ammonia, which remains in solution. The quantity added should, at least, equal the

quantity of carbonates of lime and magnesia and sulphate of lime present in solution.

When it is desired to loosen a considerable deposit, hydrochloric acid may be cautiously added at the same time. The *acetate* and *nitrate of ammonia* resemble the chloride in their action, but are neither as powerful, nor as low priced.

Chloride of Tin has been used by a French engineer. He employed about eight pounds per week for an engine working twelve hours daily. He recommends for large boilers one pound of the salt for every sixteen cubic feet of water. The chloride of tin is decomposed, forming an insoluble basic salt which is deposited, and a soluble acid salt which dissolves the lime and magnesia sediments.

It is not equal to chloride of ammonium in effectiveness, and is far too expensive for general use.

Silicate of Soda, Phosphate of Soda, Arseniate of Soda, ect., have been recommended for purifying water for special purposes, as for tanning and dyeing. They are not at all applicable in the present case.

Hyposulphite of Soda has been proposed on account of its property of increasing the solubility of sulphate of lime. It would be too expensive in practice.

Catechu, Nutgalls, Oak bark, shavings and sawdust, Tan bark, Tormentilla root, Mahogany, Logwood, etc.—These substances all contain more or less tannic acid, associated with soluble extractive and coloring matters. When they are introduced into the boiler, the soluble constituents are dissolved by the water, and basic tannate of lime is formed, which separates as a loose deposit, which does not adhere to the sides of the boiler. It is preferable to use the aqueous extract, as sawdust, chips, etc., are liable to find their way into the cocks and tubes, although they act mechanically, receiving incrustations, which would otherwise fasten themselves on the sides of the boiler. In selecting one of these substances, one would endeavor to secure the largest quantity of tannic acid and soluble extractive matter for the

lowest price. Some of these substances are said to be very effective; one half pound of catechu being sufficient for 100 cubic feet of water. From 4 to 6 pounds of oak chips have been recommended per horse power, or a half bushel mahogany chips for every 10 horse power.

Potatoes, Starch, Bran, Linseed Meal, Gum, Dextrin, Irish Moss, Slippery Elm, Marshmallow Root, Glue, etc.—These substances form, sooner or later, a slimy liquid in the boiler, which prevents more or less completely the settling and hardening of the deposits. Some of them may even hold the lime and magnesia in solution. Potatoes have been used for many years, wherever steam-engines are employed; half a peck or a peck are thrown into the boiler weekly. Linseed meal mixed with chopped straw was employed on a German railway, a peck at a time being introduced into each boiler. Some writers object to these organic substances on the ground that they are liable to cause frothing.

Sugar, Molasses, Corn or Potato Syrup.—Both cane and grape sugar form soluble compounds with lime salts, and consequently prevent their separation as incrustations. One engineer found that ten pounds of brown sugar protected his boiler for two months, another that six pounds of corn starch syrup had a similar effect. Another used molasses with success, introducing a gallon at a time.

Fatty Substances.—One writer used whale oil to prevent incrustations, two or three gallons at a time. Others smear the inside of the boiler with various mixtures of a fatty character. Stearine, mixed with wood ashes, charcoal and tar, has been recommended; or tallow with soap and charcoal diluted with oil or tar, or tallow and graphite. This plan could not well be applied to a locomotive boiler with its numerous tubes, even though it should prove effective in cylinder boilers.

Tar, Pitch and Rosin, have been applied in a similar manner.

Mechanical agents of various kinds have been employed with doubtful success to prevent the hardening of deposits on the sides of the boiler. By offering solid particles suspended in the water, they serve as nuclei for the accumulation of the calcareous sediments. *Clay* was formerly used. It was carefully sifted and washed, and introduced, five or six pounds at a time, into the boiler. It was found, however, that hard silicious particles were sure to find their way to the cylinder, scratching its surface.

Sawdust, Chips, Shavings, Straw, Powdered Glass, Scraps of Sheet Iron and Wire Gauze, have also been used and generally abandoned.

A *Wire Gauze Lining* has been proposed, and I believe, patented, as a protection against incrustations. Such an arrangement may perhaps be useful in a cylinder boiler, but could not well be applied to the tubular boilers of locomotives.

Blowing off.—The frequent blowing off of small quantities of water, say a few gallons at a time, is undoubtedly one of the most effective and simple methods for removing sediments and preventing their hardening on the sides of the boiler.

The water entering the boiler should be directed in such a way as to sweep the loose particles towards the blow-off cocks, that when these are opened they may be carried out with the water. This blowing off should take place at least two or three times daily, perhaps much oftener.

Great care should be taken to avoid emptying the boiler while there is still fire enough to bake the muddy deposits.

Washing out frequently is very efficacious.

Metallic Zinc, attached to the plates of the boiler so as to secure actual contact, is probably one of the best preventives of corrosion. As already mentioned, the iron protects the copper and brass tubes by rendering them electro-negative, being itself much more rapidly corroded in consequence. Zinc bears the same relation to iron that iron does

to copper, and may be made therefore to bear the corrosion. Rolled zinc is preferable to slabs, as the latter are very crystalline, and are consequently very unevenly corroded, soon becoming brittle and working loose.

Electro-magnetic Inductors have been proposed. One has been patented by Parry, and another, I believe, by A. F. Porter. It is claimed that these inventions prevent corrosion and incrustations, though I have seen no evidence either in their favor or against them, nor do I know their principle.

G. F. Bonsfield's Patent for protecting iron from wear by galvanic action, dated February 19, 1862, consists in insulating electro-negative bodies, copper, etc., by washers or packing of India rubber, or other non-conducting substances. I know nothing of its merits.

Incrustation powders, bearing generally the names of their proprietors, are extensively advertised and sold. They are either worthless or are sold at such extravagant prices as to make their use extremely ill-advised. I have examined several of them. Those which are at all valuable consist of one or more of the substances already mentioned, and the only novel result of their use is the payment of many times the commercial value for a fair article.

One which is put up in tin boxes, containing about one pound, at \$2.50 each, contains

Carbonate of lime.....	95.35
Carbonate of magnesia.....	0.67
Oxide of iron.....	4.15
	<hr/>
	100.17

It differs little from some of the incrustations in composition, and is of no value whatever.

Another contains

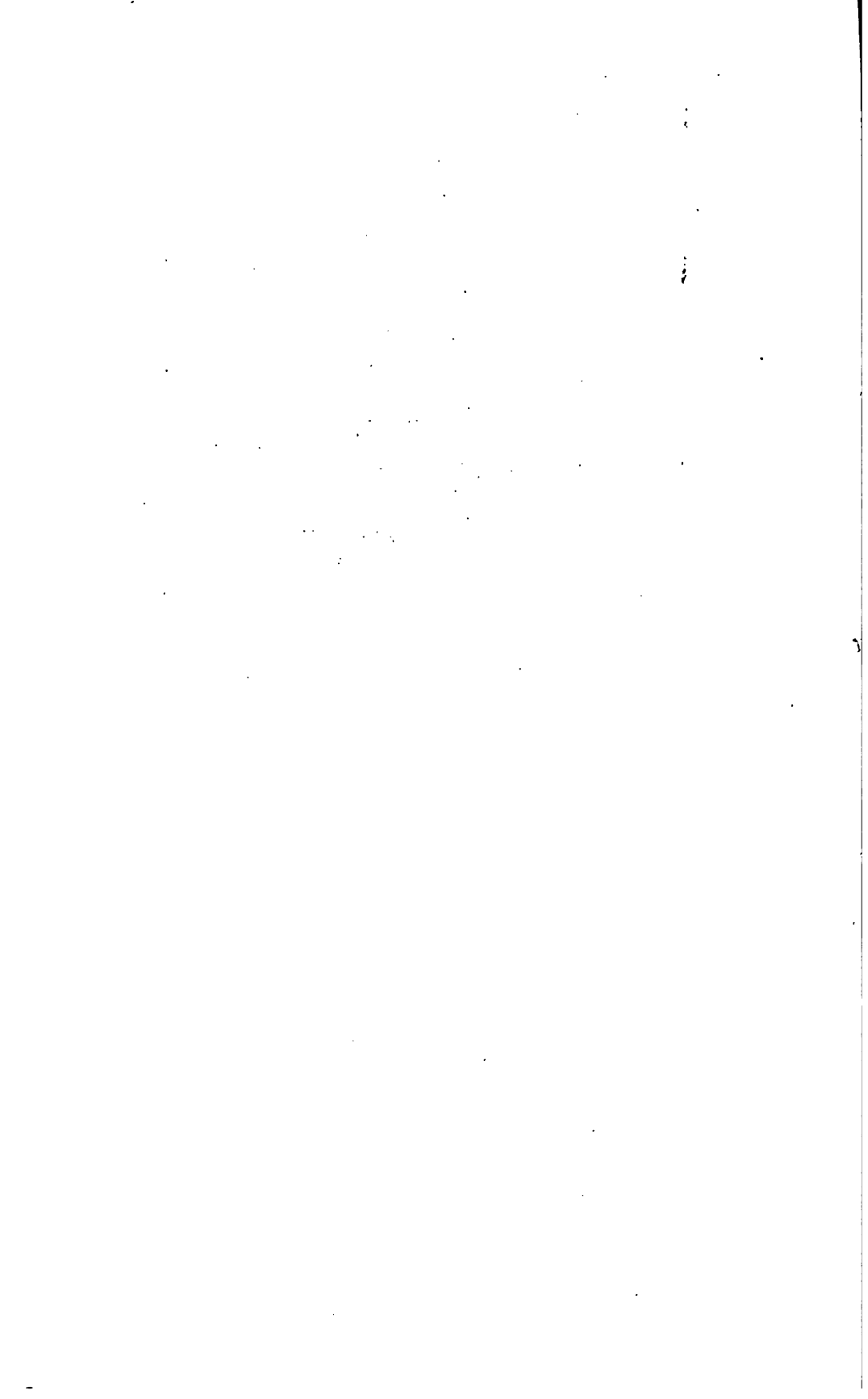
Logwood.....	75.00
Chloride of ammonium.....	15.00
Chloride of barium.....	10.00
	<hr/>
	100.00

This is a very good article, but at the price for which it is sold it cannot be used in quantities sufficient to produce much effect. In fact, chloride of barium is too expensive to be used in this country at all.

In conclusion, I would advise

1. The use of the purest waters that can be obtained ; rain water, wherever possible.
2. Frequent use of the blow-off cock.
3. That the boilers never be emptied while there is fire enough to harden the deposits.
4. Frequent washing out.
5. Experiments on the efficacy of zinc, lime water, carbonate of soda, carbonate of baryta, chloride of ammonium, some substance containing tannic acid, linseed meal, and the electro-magnetic inductor.

NEW YORK, Nov. 17, 1865.



APPENDIX.

METHOD EMPLOYED IN ANALYZING THE WATERS.

1. *Determination of silica, oxide of iron and alumina, lime, and magnesia.*—Two quarts of water were acidulated with hydrochloric acid, and evaporated to dryness in a platinum dish. The residue was moistened with hydrochloric acid, treated with distilled water and boiled. The slight residue of silica was collected on a filter and weighed. A trace of oxide of iron and alumina was then precipitated by ammonia. In the filtrate the lime was precipitated by oxalate of ammonia. After pouring off the clear supernatant liquor, the oxalate of lime was washed twice in the beaker with hot water, then dissolved in hydrochloric acid and reprecipitated by ammonia, to ensure the complete separation of the magnesia. The magnesia was then precipitated from the combined and concentrated filtrates and washings, by phosphate of soda.

2. *Sulphuric Acid.*—Two quarts of water were acidulated with hydrochloric acid, evaporated to about half a pint, and treated boiling hot with chloride of barium. The sulphate of baryta was washed, etc., as usual.

3. *Chlorine.*—Two quarts of water were made slightly alkaline with pure carbonate of soda, concentrated to about half a pint, acidulated with nitric acid, and treated with nitrate of silver. The chloride of silver was collected on a filter, washed, etc., as usual. The ashes of the filter were treated successively with nitric and hydrochloric acids, to convert the small quantity of metallic silver, reduced by the filter, into chloride.

4. *Alkalies.*—Two gallons of water were concentrated to half a pint, filtered from the carbonates of lime and magnesia and sulphate of lime, treated hot with a small quantity of chloride of barium to remove sulphuric acid, boiled with milk of lime to precipitate magnesia, and then filtered. The solution was then boiled with carbonate of ammonia and ammonia to precipitate baryta and lime, and finally with a little oxalate of ammonia to remove the last trace of lime. The filtrate, after evapora-

tion and ignition, consisted of the chlorides of potassium and sodium. The potassium was determined with bichloride of platinum.

5. *Total residue and organic matter*.—One pint of water was evaporated to dryness in a weighed platinum dish. The residue was dried at 250° F. till a constant weight was obtained. It was then ignited till the organic matter was entirely burned off, moistened with a solution of carbonate of ammonia and dried at 250° F. The treatment with carbonate of ammonia was repeated till a constant weight was obtained. The loss by ignition indicates very closely the amount of organic matter present. As a control on the determination of the alkalies, the ignited residue was moistened with dilute sulphuric acid, dried, and ignited in vapor of carbonate of ammonia till a constant weight was obtained. By deducting from this weight, calculated for one gallon of water, the combined weights of the silica, oxide of iron and alumina, and of the lime and magnesia, calculated as sulphates, the weight of the alkalies as sulphates was obtained.

6. *Carbonic acid* was not determined directly.

7. *Nitrates*, in traces, were detected in some of the waters by the proto-sulphate of iron test, but not in sufficient quantity to necessitate their determination.

8. *Distribution of acids and bases*.—As the waters were analyzed with special reference to the incrustations, it was considered best to present the lime as sulphate and the magnesia as carbonate, these being the forms assumed at the high temperature of the boiler, as proved by the analyses of the waters taken from the boilers, and of the incrustations: although, as T. Sterry Hunt has shown, bicarbonate of magnesia and sulphate of lime yield, at the ordinary temperature of the atmosphere, sulphate of magnesia and bicarbonate of lime.

Chlorine was given by preference, first to potassium, then to sodium, finally to magnesium. Had there been more than sufficient for these bases, the residue would have been combined with calcium.

Sulphuric acid was then given to, first, potassa, then to soda, then to lime. A residue after providing these bases would have been combined with magnesia.

The remaining quantities of potassa, soda, lime, and magnesia were calculated as simple carbonates.

METHOD EMPLOYED IN ANALYZING THE INCRUSTATIONS.

1. *Acids and bases*.—Three or four grammes of the powdered substance were dissolved in moderately strong hydrochloric acid. The solution was evaporated to dryness and gently heated, the residue treated with dilute hydrochloric acid, and boiled. The insoluble silica, colored generally by organic matter, was ignited and weighed as usual, and then tested for sulphate of lime, which was not detected in it in a single instance.

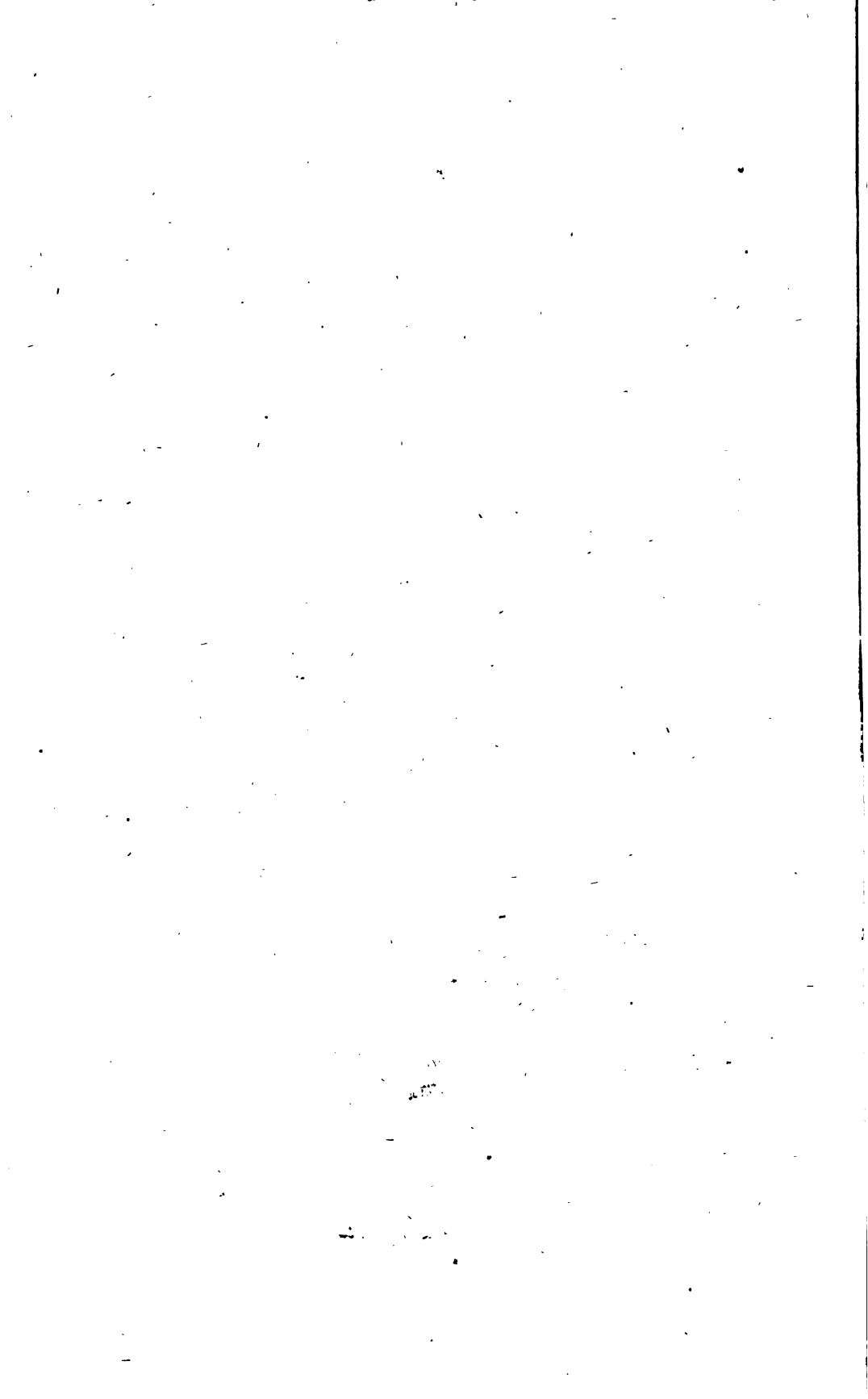
The filtrate from the silica was divided into two equal parts. In one the sulphuric acid, in the other the oxide of iron and alumina, lime and magnesia were determined as in the waters.

2. *Water* was determined by subjecting the powdered substance to a temperature of 350° F. till a constant weight was obtained.

3. *Carbonic acid and organic matter* were not directly determined.

4. *Distribution of acids and bases.*—The sulphuric acid was combined with lime. The remaining lime was combined with carbonic acid. It was then found that by calculating the magnesia as neutral carbonate, MgO , CO_2 , the analysis overran by about half the carbonic acid given to the magnesia. This fact, and the high temperature at which the incrustations are formed, warranted the presentation of the magnesia as basic carbonate, 2MgO , CO_2 .





Johnson & Co. agents.

5000 lbs. for 1000.

2

1500 lbs. for 1000 lbs. -

56500 - all charged with 1000.

16 int in 1000.

John A. Coleman
Agent
53 Kelly St.

(2)
Certificate of Boston
+ Filate of do -

1869, Nov. 6.

Gift of
Saml. A. Green,
of Boston.

A BRIEF RESUME

OF THE UNDERSIGNED'S

EXPERIENCE AND CONNECTION WITH

DR. CHAS. J. EAMES' DISCOVERY

TO PREVENT THE

INCRUSTATION OF BOILERS.

Johnson & Higgins.

THIS gentleman, whilst engaged in chemical pursuits and experiments, was impressed with certain results which he had attained, as being applicable to the prevention of the formation of scale in boilers using salt water. And after privately conducting experiments for a period of a year, which fully satisfied him of its reliable character, applied to us to undertake its practical introduction. A few interviews and a cursory examination of the principles convinced us that it was no chimerical idea, and having a just conception of its great value, if even an approximate result could be attained, of the character claimed for it, we determined to give our aid in its development.

We accordingly engaged the services of the eminent Russian engineer, Mr. N. S. Seleninoff, to make a thorough trial of the discovery in a practical way, and placed at his disposal a perfectly new boiler, constructed for wrecking purposes, with authority to apply an extreme test, even to the destruction of the boiler, if the experiment proved unsuccessful. Following this (document marked A) will be found his report. This result having been closely watched during its progress by ourselves, and being witnessed *with our own eyes*, placed the discovery beyond a question, in our judgment. For fear that there might be some unknown chemical action detrimental to the boiler, we took the precaution

to have a careful analysis, made by two experienced chemists, of residuum left in the boiler, as well as the drippings from the gauge cocks, both of which assured us on this point, as such deposits were found to consist only of the oil, dirt and filings left in all entirely new boilers. The only difficulty experienced in this trial was of a purely mechanical character dependent upon the size and arrangement of the "percolator," which subsequent trial on a sea-going vessel, enabled us to adjust.

Rumors of the experiment having got about, we were applied to by various persons for information and for the privilege of applying it; but we had determined that the discovery should assume a national character by being introduced in the navy first; and an interview was therefore sought with the Chief Engineer of the Navy, B. F. Isherwood, Esq., who immediately saw its importance and at once brought the subject before the Hon. Secretary of the Navy, who authorized a prompt trial of the same. The nature of the water in the Gulf being most destructive to boilers, over any other locality on the coast, Key West was selected as the spot where this trial was to be made. And, after the delays always incident to all such operations, the experiment formally began on the 30th of May last; and following (documents marked B and C) will be found the report and journal of the proceedings. The result, tried under the most adverse circumstances, with an old boiler already partly encrusted, with the most deleterious water that could be found, run up to a density perfectly unheard-of in using sea water, and which, without the application of this discovery, would, in the opinion of Mr. Zeller, have destroyed the boiler in forty-eight hours, was, in the highest degree, gratifying.

We deem that this report, as it is to be followed by its immediate application to vessels of the navy, justifies us in offering the discovery to the public.

The discovery and its application is as follows, *viz.* :

The salt water being taken from the side of the ship or from the hot well, (the latter saving heat,) is led into and through a filter, where the particles of water, being separated by sponges,

perforated plates and other means, are brought into contact with certain chemical agents, by which the deleterious substances in salt and other waters are immediately precipitated into an insoluble deposit. This latter is caught by sponges, &c., and the water thus rendered harmless is ready to pass into the boiler. The result will be perfect if the water passes into a tank before being drawn off and into the boiler.

The chemical compounds waste very slowly, can be carried in casks without loss, and can be supplied in any quantity. We have not as yet attained exact data as to its waste, but can state that it will require renewing at intervals of not less than sixty days; with careful use, it is believed, that it will last much longer.

In the investigations made, the succeeding article on the subject of "Boiler Deposits and Incrustations" gave us so much definite and valuable information, that we deem all persons interested in the subject will be glad to read the same; it will be found immediately succeeding this communication.

JOHNSON & HIGGINS, *Agents*,

89 Wall-street.

ON BOILER DEPOSITS AND INCRUSTATIONS.

TAKEN FROM

The Practical Mechanics' Journal, Sept., 1868.

BEING A BRIEF TRANSLATION FROM

M. Couste's Memoir on Boiler Deposits.

It is desirable to preface this subject by a brief statement of the principal conditions that affect questions of the nature, formation, or prevention of boiler deposits.

The importance of the subject to mechanical engineering, and to the public, cannot be overrated. The efficient exclusion of deposits and incrustations from innumerable land boilers of Great Britain alone, would involve the economization of millions of tons of fuel, the preservation of many lives periodically destroyed by explosion, often traceable to this as one in the train of causes; while if perfected in marine boilers, it would revolutionize much of our steamship machinery. That such possible results are recognized, is proved by the fact that more than seventy patents encumber the records at this moment, for methods presumed to mitigate or to prevent deposit or incrustation of boilers; yet amongst these it may be affirmed that there is not even one that fully answers its purpose, while the great mass consist of mere "nostrums," that only prove the general ignorance of the conditions in the problem by the inventors and by the public. I do not, therefore, suppose that any apology is required from me on the part of the translator of M. Couste's most valuable memoir, although its first appearance in its original language dates some years back; for I am myself aware that, owing probably to its having been inaccessible except in a foreign tongue, it has re-

remained up to the present time almost completely unknown to British mechanical engineers. Yet it contains a rigorous investigation of some of the most important conditions upon which depend the *only* method so far effective for the prevention of boiler deposits, namely, the continuous removal of determinate volumes of the heated fluid, so as to avoid saturation and deposition, whether partial or total.

M. Couste touches but slightly upon the chemical or mineralogical parts of the subject; he deals principally with its thermic and dynamic relations.

I propose, therefore, to preface the translation of his memoir by passing the former very briefly in review, and referring as briefly to some of the modes, patent or otherwise, proposed as remedies, and chiefly dependent on chemical relations.

Exclusive of "mine waters," or other natural waters, mineralized or polluted, and hence everywhere to be shunned for feeding boilers, and therefore rather beside our subject, the natural waters with which steam boilers are supplied for evaporation, may be divided into, 1st, Fresh water; 2d, Sea water; and the questions for the practical engineer refer to the nature of their solid contents, the causes and order of deposit of these, and to the action of their solid contents upon the boiler.

The primary effects of the solid contents of the water ceasing to remain in solution as when introduced to the boiler are, 1st, Deposition, and at a further and more or less prolonged stage, Incrustation; i. e., the induration of the previously unintegrated precipitate, whether morpious or finely crystalline.

And the immediate consequences are:

1. Interference with the full functions of the boiler in supplying steam.
2. The promotion of its destructive action by the fire and flame of the fuel upon its shell.

While the remoter consequences is the danger of explosion induced, which becomes extreme when the deposit is thick and diffused.

The destructive re-action upon the boiler again is two-fold:

1. *Mechanical*—The deposit or incrustation preventing the free

passage of heat to the water through the shell of the boiler, causing waste of fuel and overheating of the boiler, and interfering (in various constructions of boiler) with the free circulation of the fluid, upon which the rapid taking up of heat by it so much depends.

To treat fully of the last would involve the passing in review a great number of different forms and constructions of boiler, and be quite beyond our scope here.

It is enough to say, that obviously boilers with intricate interior construction, closely placed tubes and water spaces, etc., will be most liable, *cæteris paribus*, to this injurious result.

2. *Chemical*—Corrosion and destruction of the metal of the boiler due to the action of more concentrated saline matter, soluble and insoluble; and to that of the air and gases of the furnace acting on the metal brought to a higher temperature.

Both effects under this head are modified by the nature of the metal of which the boiler is constructed; and practically our steam boilers may be classed as either of iron, or of copper, or of some few of the alloys of the latter.

Boilers of iron are most acted on by air and water, and by some of the saline contents of fresh and sea water when concentrated; while copper boilers (once strongly advocated for marine purposes) are more affected by the oxidized sulphur of the coal, by the ammonia evolved from its combustion, and by the oily acids of the grease pumped into and spread about the boiler. It should be remarked in passing, however, that when sulphurous fuel is burnt at an intensely high temperature in direct contact with the boiler shell, iron is acted on with great rapidity, (whether with or without internal deposits,) and apparently by the direct formation, at the external surface of the iron shell, of successive thin coats of bi-sulphuret of iron; hence it is, as one cause, that copper fire-boxes possess their durability in locomotive fire-boxes. There are other and independent reasons for this durability, however.

In the class of natural fresh waters, the substances *most commonly* found dissolved are lime, soda, iron, magnesia, potass, alumina, and silica (the relative quantities being *usually* in the order here set down), and in combination with oxygen, chlorine,

occasionally with oxidized nitrogen, in the form of nitrates and carbonic acid.

Organic compounds of carbon, hydrogen and nitrogen, are also often present. Besides these, natural fresh waters contain air in solution, often with excess of oxygen, carbonic acid, uncombined with solid bases, and more rarely sulphuretted hydrogen.

The analysis of Thames water, by Dr. R. D. Thompson, as supplied by some of the London Water Companies, may be taken as a type of our common hard waters, receptive (more or less) of putrescible matter—and hence, of such as most commonly supply our land steam boilers.

In this city (Dublin) the well waters from the limestone gravel are much more rich in sulphate of lime, which is still more the case in the waters, for example, of the Paris Gypseous Basin. Hence, in so far, the latter are both worse than the London water as steam boiler supply—sulphate of lime forming, in fact, both in land and marine boilers, the most insoluble and intractable portion of any deposit formed.

The solid matters contained in one imperial gallon of Thames water, according to the above chemist are :

THAMES WATER.	
Chloride of Sodium,.....	16.00 grains.
Sulphate of Potass,.....	2.41
Chloride of Magnesium,.....	2.10
Carbonate of Magnesia,.....	0.50
Chloride of Calcium,.....	2.11
Nitrate of Lime,.....	0.07
Sulphate of Lime,.....	3.18
Carbonate of Lime,.....	10.70
Oxide of Iron and Alumina	0.46
Silica,.....	0.24
Organic Matter,.....	3.56
Total,.....	41.33

A boiler fed with such water (and this is not a remarkably impure one), a locomotive, for example, blowing off into steam 1,000 gallons per hour, would, at the end of 350 hours, if no deposit or solid matter were blown out or otherwise removed, contain nearly a ton of sediment.

An imperial gallon of water is capable of holding dissolved when cold (60° Fahr.), and when boiling in free air (212° Fahr.),

the following weights, nearly, of the more important of the preceding salts:—

	At 60° Fahr.	At 212° Fahr.
Carbonate of Lime,.....	merely traces.	merely traces.
Silica,.....	70 grains.	"
Sulphate of Lime,.....	170 grains.	"
Carbonate of Magnesia,.....	3.25 oz.	"
Sulphate of Potass,.....	10 oz.	40 oz.
Chloride of Sodium,.....	32 oz.	32 oz.
Chloride of Magnesium,.....	266 oz.	580 oz.
Nitrate of Lime,.....	500 oz.	" ?
Chloride of Calcium,.....	240 oz.	unlimited.

It will thus be evident that the order of depositions, as the water in the boiler becomes concentrated, is:

1. Carbonate of Lime.
2. Sulphate of Lime.
3. The Salts of Iron, as Basis or Oxides, and some of those of Magnesia.
4. The Silex and Alumina, usually with more or less of the Organic Matter.
5. Common Salt.

The carbonate of lime sometimes deposits as an amorphous mass, like hard, fawn-colored chalk, but much more usually, especially in high pressure boilers, precipitates in the crystalline form, as arragonite (one of the dimorphous forms, of which calc spar is the other). The sulphate of lime falls as amorphous gypsum most commonly, but not unfrequently in small crystals of hydrated gypsum, (the water combined in unusual proportions, as in those discovered, some years ago, by the late Professor Johnson, of Durham, Reports Brit. Ass.) segregated or coherent as a hard crust—which latter forms the worst form of "boiler scale"—and when long exposed to high temperature, becomes changed to anhydrite, with the form of crystal, and hardness of the natural mineral.

Recurring now to marine boilers, or those fed with sea or salt water—our second class.

We may take Bouillon La Grange and Vogel's analysis of the ocean water outside Bayonne, in the Gulf of Gascony, as a type of sea water. The total saline contents in a cubic foot of sea water varies, but within limits, in the ocean, and all the great tracks of navigation, that may be practically neglected. The

freshest water is probably that of the Baltic and upper part of the Black Seas—sp. gr., about 1024. The upper limit of salt is in the water of the Dead Sea—sp. gr., 1240 nearly.

The following are the solid contents of 100 parts of the Gulf of Gascony :

Chloride of Sodium.....	2.510
Chloride of Magnesium.....	0.350
Sulphate of Magnesia.....	0.578
Carbonate of Lime and of Magnesia.....	0.020
Sulphate of Lime.....	0.015
Carbonic Acid (in solution).....	0.023

3.496

The essential solid elements, as regards our subject, are the lime, sea salt and magnesia, in combination with sulphuric acid and chlorine, and very often in practice that which analysis does not show, a vast amount of suspended muddy water, which is pumped with the water into the boilers, as in the Ganges, British Channel, &c.

In minute quantity sea water, however, also contains potass, alumina, and various metals, with bromine and iodine.

The following table, by Berthier, shows the order and proportionate deposition of solid matter upon concentration, by boiling off steam from sea water, per 100 parts.

Saline Matter.	A Sea Water. sp. gr., 1.0278.	B Ditto Concentrated. sp. gr., 1.140.	C Ditto Concentrated. sp. gr., 1.230.	D Ditto Concentrated Salt nearly Deposited.
Chloride of Sodium.....	2.50	16.00	25.50	20.80
Chloride of Magnesium.....	0.35	0.46	1.07	4.85
Sulphate of Magnesia.	0.58	0.80	1.48	9.50
Carbon. of Lime and Magnesia,	0.02	0.00	0.00	0.00
Sulphate of Lime.....	0.01	0.00	0.00	0.00
Sulphate of Soda.....	0.00	2.65	2.81	0.00
Water.....	95.54	79.79	69.14	64.85
	100	100	100	100

Thus, when sea-water is boiled down so that the water is only about 65 per cent.—all the salts of lime and magnesia—the whole of the sulphate of soda formed, and a large proportion of the sea salt have been deposited, and these constitute the tough and hard cake of salt, with imperfect crystallization, arranged perpendicu-

larly to the heated surface, i. e., the shell, that is so destructive and inconvenient in marine boilers.

In the state of concentration of D, the sea water is a strong brine, with a high boiling point. The elevation of the latter is shown by the following table, from Faraday's past experiments:

Volume of Sea Water.	Boiling Temper. at 30° Barom.	Saline matter in 100 parts.	Nature of Deposit.
1000	214° Fahr.	3.0	None.
299	217° "	10.0	Sulphate of Lime.
102	228° "	29.5	Common Salt.

Thirty-seven parts of common salt saturate 100 of water, at all temperatures, if both be pure, according to Fuchs, but when the other contents of sea water are present, 36 parts saturate at 226° Fahr., and 30 parts at 228°. The loss of solubility *augmenting* with the temperature, hence 10 volumes of sea water concentrated to one, becomes, in part, saturated brine.

M. Couste has noticed also analogous facts with reference to the sulphate of lime.

We may now pass briefly in review the several methods that have been proposed or tried for mitigating or preventing these injurious deposits. To attempt to go through these *seriatim*, or even the patented ones only, would be impossible, and a bootless labor. They may be classed, however, under the following heads: and first, as respects land boilers evaporating fresh water.

1. Filtration of the water—an obvious preliminary that should invariably be adopted when the water contains suspended mineral matter, but which does not affect dissolved salt, for, although long continued filtration and moving contact with solids, such as flint pebbles, will deprive water even of some of its soluble contents, the process carried to this extent is too costly for our purpose.
2. The application of collecting vessels to the boilers. These are of two sorts. A, external close vessels, heated by otherwise waste flue heat, into which the feed water of the boiler is primarily admitted, and passes thence to the boiler.

The function of such a vessel is that the lime held in solution as bi-carbonate, by the excess of carbonic acid dissolved in the water, is partially precipitated in the vessel as carbonate, the carbonic acid being driven off by the heat.

This constitutes Brunton's patent for sediment vessels.

It has also been proposed to adopt Dr. Clarke's water purifying process to the feed water entering boilers, and to precipitate the bi-carbonate of lime by adding measured volumes of lime water, so as to form proto-carbonate. Like all other devices that aim at changing the water by chemical means, however, it is too delicate in application, and any excess of lime would obviously only add to the evil.

I may state here, upon the authority of my own researches of past years, that the carbonic acid is evolved, and the carbonate of lime begins to deposit, as soon as the feed water is heated to 190° Fahr.—(Reports Brit. Ass. Reports on Iron Corrosion.)

B. Internal collecting vessels, proposed by many separate inventors long since, and patented several years ago by Mr. Scott. These contrivances depend upon the fact that the solid matter when first separated from solution, and floating about in the agitated boiling water of the boiler, will find a resting place, and precipitate, *i. e.*, collect, in any part of the boiler, where we may provide for it a quiet spot, free from agitation of the water.

Hence, if a narrow necked vessel, as a bottle or pan, be placed within or hung up in a steam boiler, the water, though at 212° within it, does not circulate in brisk currents, and gradually the floating particles, as they pass its mouth, fall into this collecting vessel, deposit, and never return from it. This does, in reality, constitute one of the most efficient means known of collecting the deposit to one point, so as to preserve the rest of the boiler surface free, comparatively. It can be readily removed from the collecting vessel.

To this division belongs also the plan often adopted, of putting

balls of wood, or brick, or stone, &c., into the boiler, which roll about with the agitated water, and segregate some of the deposit in coat after coat upon their surfaces. This notion is very ancient, and has been known in domestic life—housewives putting a boy's marble into their tea-kettles with a similar object.

The two methods, A and B, may be combined; and I have in my own practice found the combination advantageous—an external sediment vessel heated by the waste flue heat receiving the feed water, and in it the greater part of the carbonate of lime is left; while internal collecting vessels in the boiler receive the greater part of the remainder, in combination with the sulphate of lime. This method also, though long previously in use, has been patented by Taylor.

3. The addition of foreign materials to the water of the boiler, with a view to prevent the aggregation of the particles of the deposit, and their adherence to the walls of the boiler.

The substances proposed with this end in view are numerous.

Potatoes, oatmeal, bran, sawdust, molasses, coal-tar, charcoal dust, smiths' dust,—i. e., finely divided coke and ashes,—coal ashes, plumbago, soap, tallow, and many others have been added in more or less bulk to the water in the boiler before closing the main lid after cleaning. All of these, and more especially such matters as potatoes or sawdust, possess some power of subdividing and making more friable calcareous deposits, and are not without some use when much sulphate of lime is present in the water, as they greatly interfere with its crystalization into massive crusts; but their effort is temporary, and all such additions are attended more or less with the serious evils of "priming," i. e., water being driven over with the steam into the steam pipes and valves of the engine from the boiler, and with it solid matter, which chokes the passages, spoils the valve faces, &c. To this class of mitigants belongs the useless and expensive nostrum, long in use "by authority" in the Royal Navy, of coating the whole inside shell of the boiler (in steam ships) with tallow and black lead mixed together, under the notion that it prevented the adhesion of deposited salt. It is believed that this is long discontinued.

4. In addition to the water in the boiler, or to the feed water entering it, of chemical agents intended to render the less soluble salts in the water more soluble, and therefore less capable of forming deposits.

Very many of the nostrums that have from time to time been patented with this alleged object, have been incapable of any such action. They have often been educts of chemical or other manufactures, sought to be profitably got rid of, and not unfrequently of a character likely to be highly prejudicial to iron boilers. Thus soluble salts of arsenic and copper have been sold for this purpose. The chief agents that have been proposed with intelligent views, however, have been hydrochloric acid, more or less diluted; chloride of ammonia (sal ammoniac), which constituted the matter of Ritterbandt's patent of 1850 or 1851; and chloride of calcium (an educt of many chemical manufactures). None of these are particularly effectual. Hydrochloric acid is a perilous addition to any iron boiler, as a very slight excess, when continued, will remove a large proportion of the thickness of the shell of the boiler in solution, as chloride of iron.

Sal ammoniac and other soluble chlorides are not free from this risk (for in presence of organic vegetable matter, iron is capable of decomposing slowly even common salt, and by a remarkable train of decomposition producing carbonate of soda, and evolution of free chlorine, which in turn re-acts upon the iron), and none of these agents have any advantageous action upon water rich in sulphate of lime.

Alkaline solutions, carbonate of soda, and caustic soda, have also been proposed, on the ground of their presence rendering the difficultly soluble salts of lime more soluble; but their action in this way is not marked, and the fact in practice is, that the alkaline water is carried up, more or less, with the steam into the pipes and engines, &c., and acts upon all flanches, joints, packings, paint, &c., as a destructive agent. Besides these, tan-pit liquor, decoction of oak bark, catechu, and various other astringent substances, have been strongly recommended by their several proposers; and perhaps strangest of all, dyewoods, and various vegetable coloring matters, constituted the subject of a patent of

1838,—of all of which we may safely say, that any other “chip in the porridge” would have been quite as useful.

- Lastly, we arrive at the methods that have been proposed or adopted for mitigating or preventing deposit in marine boilers working with sea water.

In order of time, the first of these was the very primitive one of “blowing off,” that is to say, that the sailing engineer, at stated intervals fixed by experience, permitted the feed pumps to work an excess of feed water into the boilers, and then blew off at the sea-cocks fixed into the bottom parts of the boilers, thus removing at such operation some of the muddy deposit of saline matter at the bottom cells of the boiler, and with it some of the denser and more concentrated brine. Occasionally the order of the process was reversed, the blowing off preceding the feed in excess of the average consumption of water in steam, but with the danger of laying bare some of the flue plates when the water was thus lowered. However, like every “rule of thumb” method, and in common with all dependent upon personal care and continuous attendance, this was often perilously neglected; and in my own early practice as a mechanical engineer, I have known the London steamships come into the port of Dublin with every “pocket” or side chamber, beside the furnaces of their boilers, choked up with one solid mass of salt, that could only be removed by cutting the side plates out and replacing them.

The inventions of Hall and others for providing marine engines with surface condensation, and hence working with fresh water only, the same water being evaporated over and over again, had amongst other objects in view the relief of this great evil; and it is now highly probable that eventually this form of engine will be made fully available, and will displace the use of feeding with sea water.

They failed at first, however, and the invention and perfecting of the boiler-feeding arrangements known as the Brine Pump, and of the salinometer, displaced in all well-provided steamships the old system of blowing off.

The brine pump is an adjunct of the feed pump, and its function is to remove at each stroke of the engine a determinate

volume of the water; withdrawn from that part of the boiler supposed to be most highly concentrated as a saline solution, while the feed pump supplies in its place a larger determinate volume of sea water in its natural state. The cold sea water to be pumped into the boiler is caused to pass through tubes immersed in the boiling saline liquid, being pumped out by the brine pump, and robbing the latter of some of its heat, economizes part of the fuel that would be otherwise wasted.

The salinometer (one of the earliest promoters, if not proposers, of which was Mr. Scott Russell) is in fact an areometer or hydrometer, by which the specific gravity of the liquid within the boiler, and at various levels may be tested. There are various constructions, some always presenting indications, more or less exact, of the density of the fluid actually within the boiler, others requiring a certain volume of the hot liquid to be drawn off for trial—all depend upon the common principle of the areometer, the floating or not of bodies of known density immersed in the liquid, with adjuncts for correction as to temperature, &c.

The brine pump is often used without the salinometer—still oftener with it, but independently of its necessary control. But in the most complete arrangements the salinometer itself is contrived so as to regulate the proportion between the volume of water withdrawn and that needed to be supplied by the feed pump.

This was done on board the *Don Juan*, as an early example by the salinometer (in this case a large copper sphere, with considerable buoyancy) acting directly upon the valves of the brine pumps and feed pumps. A want of sufficient mechanical power for complete and trustworthy control was, however, I believe, always found; and a much better arrangement, although one that I am not aware has ever been before proposed or tried, would appear to be the adaptation to this use of Dr. Ure's thermostat—making the *temperature only* of the fluid in the boiler, or rather coming through the brine pump out of it, the rule as to saturation, and causing the powerful flexure of the thermostat bars (which may be quite immersed within the boiler or its pipes) to act directly upon the valves regulating the supply.

It scarcely needs pointing out that no chemical, or other agents

introducible to marine boilers, are capable of producing the slightest practical effect upon the enormous volume of water evaporated, and of saline matter in a state of deposit.

If the boiler contains 100 parts of sea water, and the parts evaporated for steam in a given time be $= s$, and if n be $=$ the volume pumped out in order to preserve the state of saline concentration constant at a , $=$ (a fraction) parts of solid saline matter, then, as there is 3 per cent. of saline matter in sea water (in round numbers)—when

$$3(s + n) = a n.$$

The amount of saline matter entering the boiler by the feed pump, and removed by the brine pump, will be equal; and in this case the brine pump must remove

$$n = \frac{3s}{a - 3} \text{ volumes.}$$

If $a = 30$, which is the saturated point for common salt—one-ninth of the feed water must be removed by the brine pump, and as $\frac{1}{6}$, the fuel that will convert water into steam from a given temperature, will bring it to 212° , the loss of fuel by this inward influx of cold water to the boiler, and removal of boiling water, will be—

$$\frac{1}{6} + \frac{1}{9} = \frac{1}{54} \text{ of the whole quantity,}$$

assuming that none of the heat were returned to the boiler by conduction, between the issuing and entering fluids, as explained.

This somewhat crude view of this part of our subject will serve to illustrate the main question, to the more complete solution of which M. Couste's Memoir is dedicated.

[A]

FIRST EXPERIMENTAL TRIAL OF KAMES'S DISCOVERY.

NEW-YORK, *June 1st, 1863.*

The experiment with the apparatus for preventing incrustation of boilers was made under my direction and in my presence. The experiment commenced on the 28th of April, 1863, and was continued for 10 days.

The boiler experimented on was a new and perfectly clean locomotive boiler, having 10 square feet of grate surface, and 158 square feet of heating surface, and holding 454 gallons of water. It was placed on the dock at the foot of E. 45th Street, in Messrs. Collyer's Ship Yard.

Water used for evaporation was taken from the river and, before entering the boiler, was passed through the apparatus.

The main object of the experiment being to evaporate a quantity of water sufficient to demonstrate the principle of the apparatus used; the steam, which was kept at the pressure of 40 lbs. per square inch, was allowed to escape in the air.

The firing of the boiler was retained nearly uniform, the coal weighed, and densities of river water and of that in the boiler were hourly ascertained.

The density of river water was tested by the United States standard hydrometer. The density of that in the boiler was ascertained by the salinometer generally used by vessels running in salt water.

This latter density was ascertained at constant temperature of 190° F.

The following are the results obtained from the experiment:

The density of river water during the experiment showed, on an average, 10° hydrometer.

The density of water in the boiler, at the commencement, was at 0° of the salinometer. It increased daily, and

After evaporation of .781 gallons, it stood at 1.32			
"	"	2041	" " 2.32
"	"	3965	" " 3.32
and	"	4636	" the whole quantity

of water evaporated, it stood at 2° below 3.32.

The quantity of water blown out was as follows:

At the density of 2.32 there had been blown out in try cock testing, &c., $7\frac{1}{2}$ gallons,

"	"	1° below 2.32	"	"	15	"
"	"	$1\frac{1}{2}$ ° " 2.32	"	"	30	"
"	"	2° " 3.32	"	"	30	"

Total quantity of water blown out, $82\frac{1}{2}$ "

Total quantity of water evaporated as stated above, 4,636 "

At the end of the experiment the boiler was examined and found entirely free from any scale whatever. The iron and stays of the boiler presented the same appearance as at the commencement.

At the bottom of the boiler some sediment was found which ran off with the rest of the water in emptying.

(SIGNED,)

N. S. SELENINOFF,

(Late Engineer in the Russian Navy.)

[B]

(Copy.)

U. S. FLAG-SHIP "DALE,"

KEY WEST, June 8th, 1864.

SIR,—The "Scale Preventer" of Dr. C. J. Eames, attached to the distilling apparatus at Key West, has been in operation since the morning of the 30th of May last, until to-day at noon, when the experiment was closed, at the request of the inventor, as he desires to return North by steamer that is to sail to-morrow. Both stills were in constant operation, day and night, and the small leaks from the shell of the boiler, together with the continuous drain from the salinometre-pot, was sufficient to maintain the density of the water in the boiler at $3\frac{3}{8}$ of $\frac{1}{4}$. The salt which accumulated at the leaks about the shell of the boiler was tested frequently, and no trace of lime was discovered. The water was frequently drawn from various parts of the boiler, the chemical test applied to it, without showing any traces of lime whatever. This test was finally applied to the water, after the experiment was closed, and with the same result. To-night the boiler was emptied, and the hand-hole plates were removed, as well as the man-hole plate immediately over the tubes. The tubes were found to be entirely free from scale, and remarkably clean. Where the crown sheets over the furnace had been scaled before the experiment was commenced, (abreast the hand-holes,) no scale whatever was found, and the old scale, about $\frac{1}{4}$ of an inch thick upon the crown sheets, had become saturated with the salt water in the boiler, and so loosened it that, with my naked fingers, I picked off quite large

pieces. A jack-knife introduced under the edge of this old thin scale detached flakes four and five inches long. This scale had become quite black on both sides, and, when broken, the fractured edge was quite dark. The water adhering to the crown pieces had an inky appearance, which I attribute to dirt having been left in the boiler. In short, I am satisfied that salt water, highly concentrated, when deprived of its elements of lime, will detach the old scale in a boiler.

The inventor having informed me of the chemical agents that he employs, and as this experiment has taught me the *modus operandi* of using them correctly, I am prepared to continue this experiment, if the Department deems it at all necessary.

I examined one percolator after it had been in use three days and nights, and from the very slight wasting away of the chemical ingredients, I judged it would not cease to operate for two or three months, on the same scale that I used it.

I shall take the liberty of attaching this apparatus to the boiler of the "Honeysuckle," it being built for fresh water and high pressure steam, and since that little vessel has been here, two-thirds of her time has been occupied in scaling and repairing it. The Admiral Commanding has directed me to request you will send me a *very* large quantity of the chemical ingredient, with permission to attach the "Scale Preventer" to the boilers of all the vessels in the squadron. The regular men-of-war have surface condensers. At all events send enough for the "Honeysuckle."

The Department would save an enormous amount of time in scaling and repairing boilers by ordering Eames' "Scale Preventer" for *every vessel in the navy*.

I am, respectfully,

Your obedient servant,

THEO. ZELLER,

Fleet Engineer.

Chief Engineer

B. F. ISHERWOOD, U. S. N.,

Chief of Bureau of Steam Engineering.

[C]

(COPY.)

Log, showing density of Water, pressure of Steam, and pounds of Coal used per hour during experiments with Eames' "Scale Preventer."

Monday, May 30th.

HOOR.	SAT.	STEAM.	LES. COAL	REMARKS.
A. M.				
1				From 4 to 8, steam formed at 6.40. Commenced condensing at 7.40, with both condensers. Signed, JNO. F. KENEALY.
2				
3				
4				
5				From 8 to mer. Stopped condenser at 11.45 on account of not receiving coal. Stopped at 12. Signed, P. J. McMAHON.
6				
7	$\frac{7}{8}$	10		
8	$\frac{7}{8}$	15		
9	"	15		
10	"	19		
11	"	19		
12	"	18		
P. M.				
1	$1\frac{1}{8}$	15		From mer. to 4. Two condensers in operation. Signed, THEO. BREEZE.
2	"	15		
3	"	15		
4	$1\frac{1}{4}$	20		
5	$1\frac{5}{8}$	20		From 4 to 8. Running forward and after condensers; pumps working well. Signed, JNO. F. KENEALY.
6	$1\frac{3}{4}$	20		
7	$1\frac{7}{8}$	20		
8	"	20		
9	$1\frac{5}{8}$	22		Condensing water. Signed, P. J. McMAHON.
10	$1\frac{3}{4}$	20		
11	"	20		
12	"	22		

Tuesday, May 31st.

HOOR.	RAT.	STEAM.	LES. COAL	REMARKS
A. M.				
1	1 $\frac{7}{8}$	20		From mid. to 4. Stopped condenser $\frac{3}{4}$ of an hour, to make steam. Signed, THEO. BREEZE.
2	1 $\frac{7}{8}$	15		
3	1 $\frac{7}{8}$	15		
4	2	12		
5	2 $\frac{1}{4}$	18		From 4 to 8, as per column. Running forward and after condenser. Signed, JNO. P. KENEALY.
6	2 $\frac{1}{4}$	20		
7	2 $\frac{3}{8}$	20		
8	2 $\frac{3}{8}$	20		
9	2	20		From 8 to mer. Condensing water with one condenser. Signed, P. J. McMAHON.
10	2 $\frac{1}{4}$	20		
11	2 $\frac{1}{4}$	20		
12	2 $\frac{3}{8}$	20		
P. M.				
1	2 $\frac{1}{4}$	15		From mer. to 4. Condensing water with one condenser. Signed, THEO. BREEZE.
2	2 $\frac{3}{8}$	15		
3	2 $\frac{3}{8}$	15		
4	2 $\frac{3}{8}$	15		
5	2 $\frac{1}{2}$	20		From 4 to 8, as per column. Condensing with both condensers; pumps working well; keyed up the pumps at 5.40. Signed, JNO. F. KENEALY.
6	2 $\frac{1}{2}$	20		
7	2 $\frac{5}{8}$	20		
8	2 $\frac{5}{8}$	20		
9	2 $\frac{5}{8}$	24		From 8 to mid. Condensing water with both condensers. Cleaned the fire at 10.15. Signed, P. J. McMAHON.
10	2 $\frac{3}{4}$	20		
11	"	20		
12	"	20		

Wednesday, June 1st.

HOURL.	SAT.	STEAM.	LES. COAL	REMARKS.
A. M.				
1	2 $\frac{3}{4}$	20		Condensing water with one condenser. Signed, THEO. BREEZE.
2	2 $\frac{7}{8}$	"		
3	2 $\frac{7}{8}$	"		
4	3	"		
5	3	"		Cleaned fire at 4.30. Keyed up swell pump at 4.50, running both condensers. Signed, JNO. F. KENEALY.
6	3	"		
7	3 $\frac{1}{8}$	"		
8	3 $\frac{1}{4}$	"		
9	3 $\frac{1}{8}$	"		Changed filtering apparatus at 10 ; running both condensers. James Fields, 1st class fireman, had got his fingers cut off with pumps. Signed, P. J. McMAHON.
10	"	"		
11	"	"		
12	"	"		
P. M.				
1	3 $\frac{1}{8}$	20		Running the condenser. Signed, THEO. BREEZE.
2	"	"		
3	2 $\frac{7}{8}$	"		
4	2 $\frac{3}{4}$	"		
5	2 $\frac{7}{8}$	"		Running both condensers. Pumps working well. Signed, JNO. F. KENEALY.
6	"	"		
7	3	"		
8	3	"		
9	3	"		Running the condenser. Signed, P. J. McMAHON.
10	3	"		
11	3 $\frac{1}{8}$	"		
12	"	"		

Thursday, June 2d.

HOOR.	SAT.	STEAM.	LBS. COAL.	REMARKS.
A. M.				
1	2 $\frac{1}{2}$	20		From mid. to 4. Stopped condensing to clean fire and make steam. Fire being very dirty. Signed, THEO. BREEZE.
2	"	"		
3	"	10		
4	"	"		
5	2 $\frac{3}{4}$	18		From 4 to 6. Wooded furnace and started fire at 4.30 running both condensers. Signed, JNO. F. KENEALY.
6	2 $\frac{7}{8}$	20		
7	3	"		
8	2 $\frac{7}{8}$	"		
9	"	"		From 8 to mer. Running both condensers. Signed, P. J. McMAHON.
10	"	"		
11	3	"		
12	3 $\frac{1}{4}$	"		
P. M.				
1	3 $\frac{3}{8}$	20		From mer. to 4. Running one condenser. Puttied up around smoke-head door. Signed, THEO. BREEZE.
2	3 $\frac{3}{8}$	"		
3	3 $\frac{1}{4}$	"		
4	3 $\frac{1}{4}$	15		
5	3 $\frac{3}{8}$	20		From 4 to 8. Running both condensers. Signed, JNO. F. KENEALY.
6	3 $\frac{5}{8}$	"		
7	3 $\frac{1}{2}$	"		
8	3 $\frac{3}{4}$	"		
9	3 $\frac{1}{2}$	22		From 8 to mtd. Running both condensers. Signed, P. J. McMAHON.
10	"	"		
11	"	20		
12	"	"		

Friday, June 3d.

HOOR.	SAT.	STEAM.	LES. COAL.	REMARKS.
A. M.				
1	3 1/2	22		Running both condensers; cleaned fire at 2. Signed, THEO. BREEZE.
2	"	20		
3	"	"		
4	"	"		
5	3 3/4	"		As per column, cleaned fire and started forward and after condensers at 4.50. Signed, JNO. F. KENEALY.
6	3 1/2	"		
7	3 3/8	"		
8	3 3/8	"		
9	3 5/8	"		Running both condensers. Signed, P. J. McMAHON.
10	3 5/8	"		
11	3 1/2	"		
12	3 1/2	"		
P. M.				
1	3 3/8	20		Running one condenser. Signed, THEO. BREEZE.
2	3 1/8	"		
3	3 3/4	"		
4	4	"		
5	3 7/8	"		Running both condensers, freshened water in boiler at 7.30. Signed, JOHN F. KENEALY.
6	3 7/8	"		
7	4	"		
8	4	"		
9	3 3/4	"		Running one condenser. Signed, P. J. McMAHON.
10	3 3/4	"		
11	3 7/8	"		
12	3 7/8	"		

Saturday, June 4th.

HOUE.	SAT.	STEAM.	LES. COAL.	REMARKS.
A. M.				
1	3¾	20		Running one condenser. Signed, THEO. BREEZE.
2	3½	"		
3	3½	"		
4	3⅝	"		
5	3¾	"		
6	3⅝	"		Running both condensers. Signed, JOHN F. KENEALY.
7	3½	"		
8	3⅝	"		
9	"	"		Running both condensers, changed filtering ap- paratus at 10. Signed, P. J. McMAHON.
10	"	"		
11	"	"		
12	"	"		
P. M.				
1	3½	"		Running the condensers. Signed, THEO. BREEZE.
2	3¼	"		
3	3½	"		
4	3½	"		
5	3¾	"		
6	3½	"		Running both condensers. Signed, JOHN F. KENEALY.
7	3¾	"		
8	"	"		
9	"	"		Running both condensers. Signed, P. J. McMAHON.
10	"	"		
11	"	22		
12	"	20		

Sunday, June 5th.

HOOR.	RAT.	STEAM.	LBS. COAL	REMARKS.
A. M.				
1	3 1/2	20	312	From mid. to 4, running a condenser. Signed, THEO. BREEZE.
2	"		156	
3	"			
4	3 5/8			
5	3 3/4			From 4 to 8, running both condensers. Signed, JNO. F. KENEALY.
6	"		234	
7	"		156	
8	"			
9	"		312	From 8 to mer., running both condensers. Signed, P. J. McMAHON.
10	"	22	156	
11	"	20	78	
12	"		156	
P. M.				
1	"			From mer. to 4, running both condensers. Signed, JAMES WARD.
2	"			
3	"			
4	"			
5	"			From 4 to 8, running both condensers. Signed, JNO. F. KENEALY.
6	3 7/8			
7	3 5/8			
8	3 3/4			
9	"			From 8 to mid., running both condensers. Signed, JNO. F. KENEALY.
10	"			
11	"			
12	"			

Monday, June 6th.

HOURL	SAT.	STEAM.	LES. COAL	REMARKS.
A. M.				
1	3 $\frac{3}{4}$	20	78	From mid. to 4, running both condensers. Signed, JAMES WARD.
2	"			
3	"			
4	"			
5	4			From 4 to 8, running both condensers. Signed, JNO. F. KENEALY.
6	3 $\frac{3}{4}$		156	
7	"		312	
8	3 $\frac{7}{8}$		156	
9	"		312	From 8 to mer., running both condensers. Signed, P. J. McMAHON.
10	"		78	
11	"		78	
12	"		156	
P. M.				
1	"			From mer. to 4, running both condensers. Signed, JAMES WARD.
2	"			
3	"		78	
4	"		78	
5	"		156	From 4 to 8, running both condensers. Signed, JNO. F. KENEALY.
6	"		77	
7	3 $\frac{3}{4}$		156	
8	3 $\frac{7}{8}$		156	
9	"		78	From 8 to mid., running both condensers. Signed, P. J. McMAHON.
10	"		156	
11	"		78	
12	"		156	

Tuesday, June 7th.

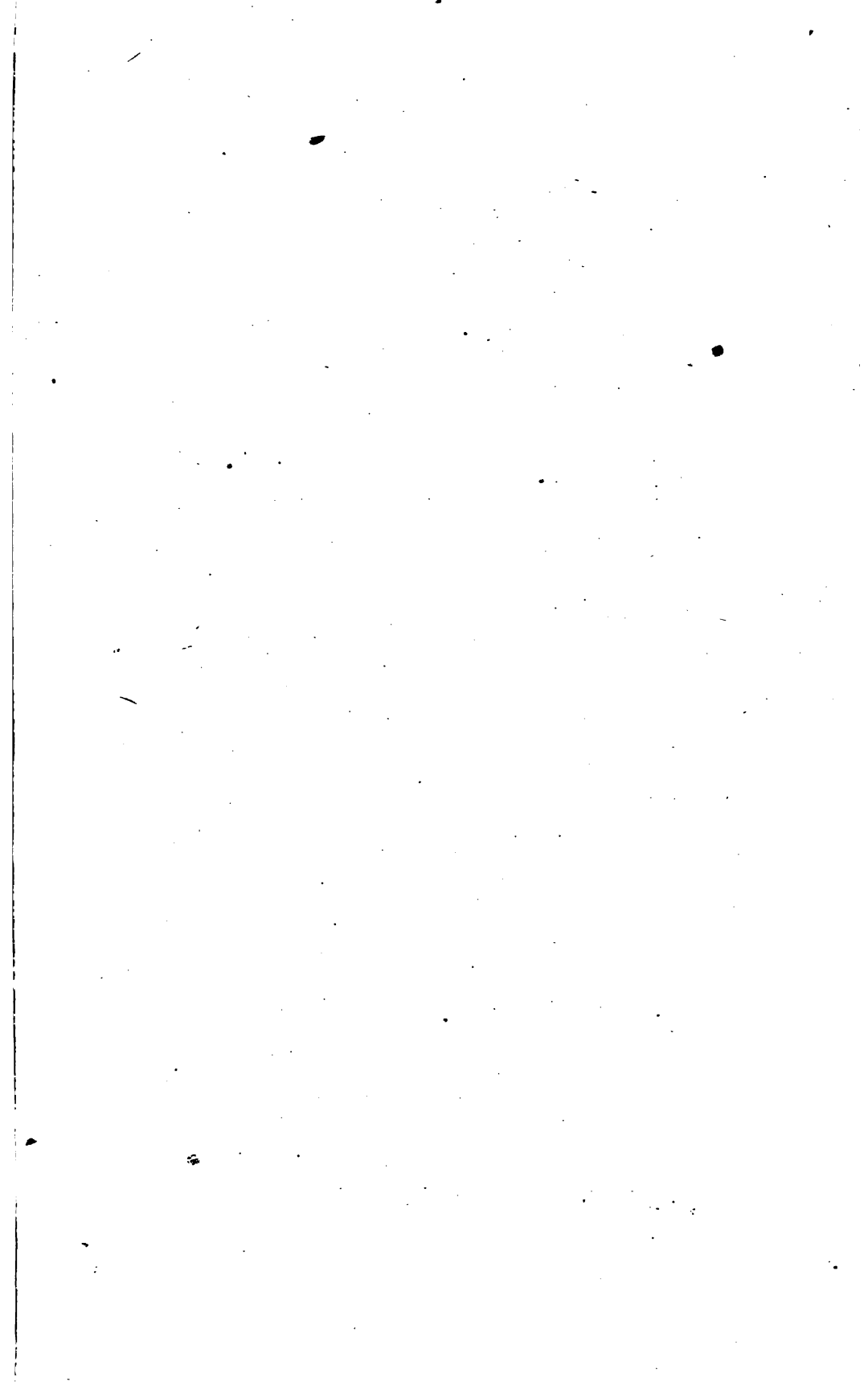
HOOR.	SAT.	STEAM.	LES. COAL.	REMARKS.
A. M.				
1	37%	20	156	From mid. to 4, running both condensers. Signed, JAMES WARD.
2	"	"	156	
3	"	"	78	
4	"	"	"	
5	"	"	"	From 4 to 8, running both condensers. Signed, JNO. F. KENEALY.
6	"	"	"	
7	"	"	156	
8	"	"	"	
9	"	"	"	From 8 to mer., running both condensers. Signed, P. J. McMAHON.
10	"	"	"	
11	"	"	78	
12	"	"	"	
P. M.				
1	"	"	156	From mer. to 4, running both condensers. Signed, JAMES WARD.
2	"	"	78	
3	"	"	"	
4	"	"	"	
5	"	"	234	From 4 to 8. Cleaned fire at 5.50. Started pump at 6.10. Running both condensers. Keyed pump up. Signed, JNO. F. KENEALY.
6	"	"	"	
7	"	"	"	
8	"	"	"	
9	"	"	78	Running both condensers. Signed, P. J. McMAHON.
10	"	"	"	
11	"	"	"	
12	"	18	156	

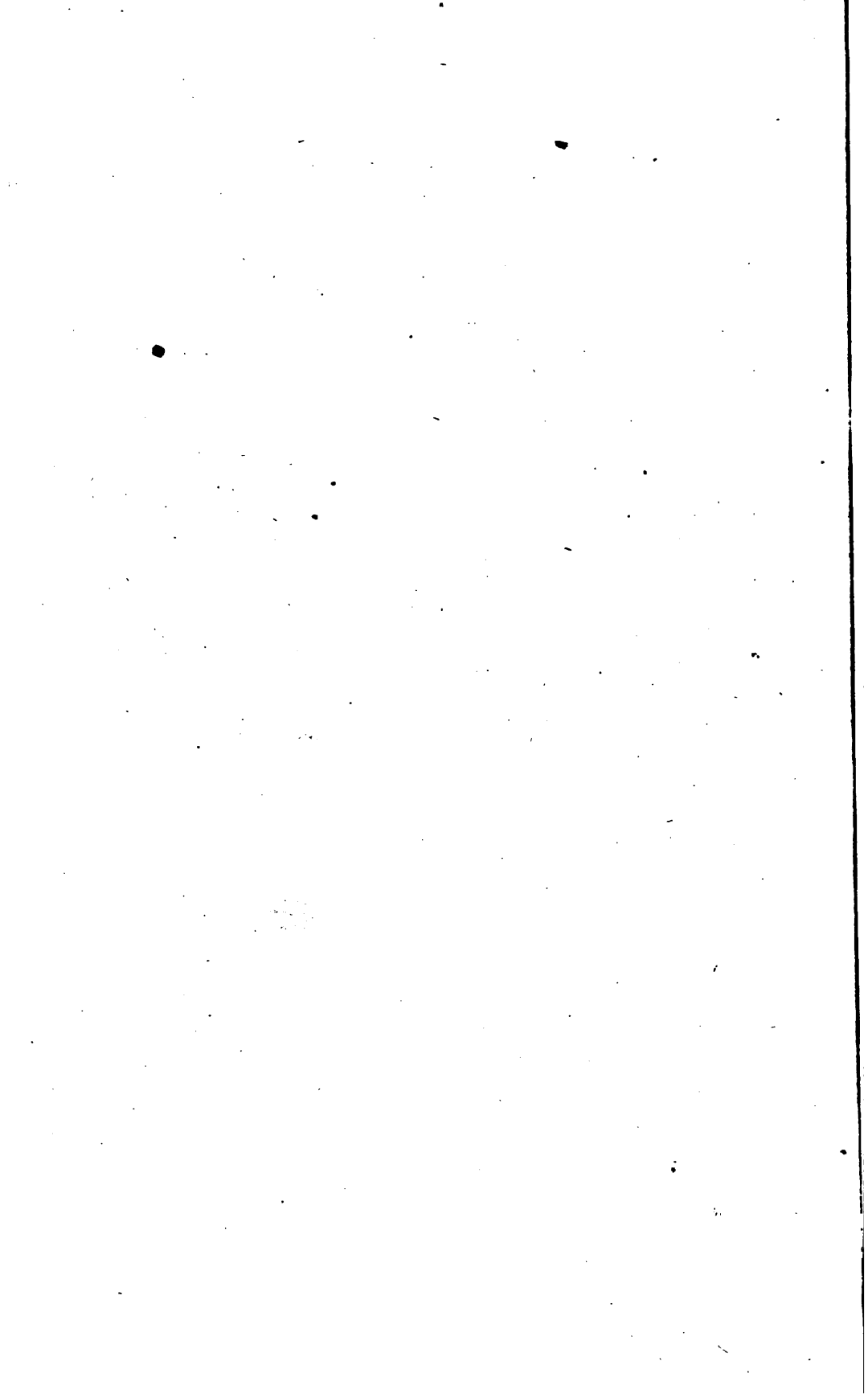
Wednesday, June 8th.

HOOR.	EAT.	STEAM.	LES COAL.	REMARKS.
A. M.				
1	37/8	20	78	From mid. to 4, running both condensers. Signed, JAMES WARD.
2	"	"	"	
3	"	"	"	
4	"	"	"	
5	"	"	156	From 4 to 8, running both condensers. Signed, JNO. F. KENEALY.
6	"	"	156	
7	"	"	78	
8	"	"	"	
9	4	"	"	From 8 to mer., running both condensers. Stop- ped condensing and hauled fire at 12. Signed, P. J. McMAHON.
10	"	"	"	
11	"	"	"	
12	"	"	"	
P. M.				
1				Total amount of Coal delivered during the experiment with Eames' "Scale preventer," by the U. S. Coal Weigher, at Key West, 15 tons 1,960 lbs. This amount includes that burnt be- fore any log or date was kept by the engineers or watches were ordered. Say 30 hours. Amount remaining at the close of experiment, 4,290 lbs. Signed, THEO. ZELLER, Fleet Engineer.
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				













NOV 1 1884

Eng 2668.65
Report on water for locomotives and
Cabot Science 004363369



3 2044 091 999 359